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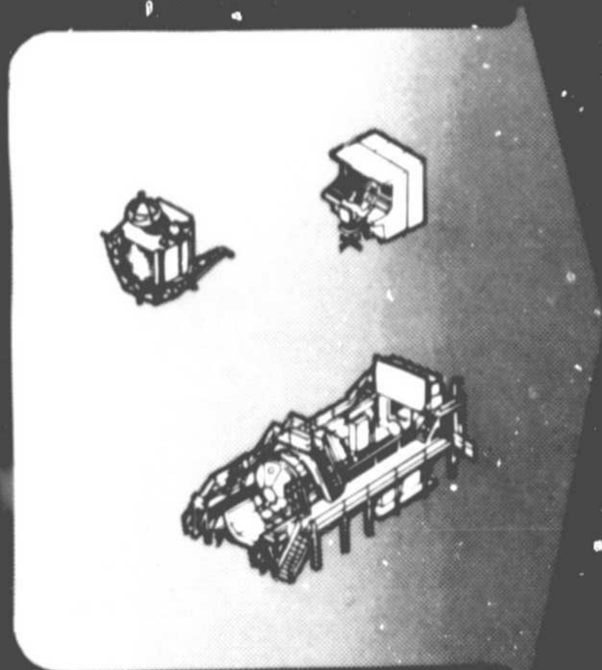

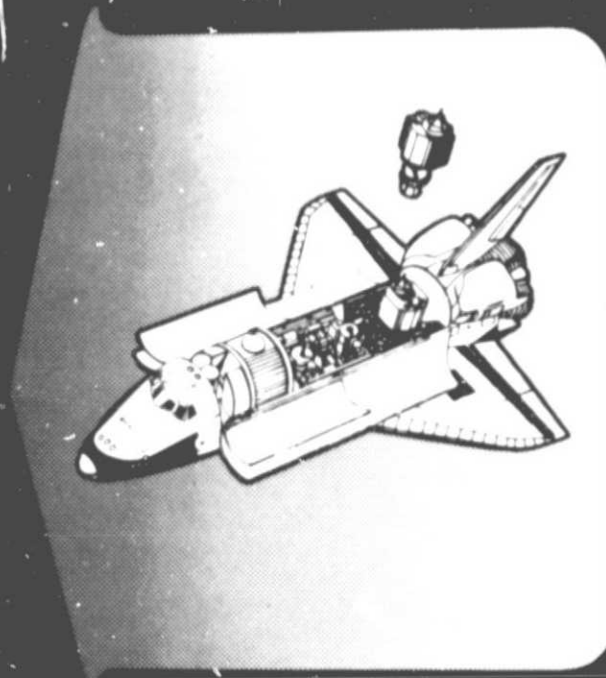

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SPACELAB PROGRAM

CONVERSION OF SPACELAB TO PACKET DATA FORMAT (FLIGHT SYSTEM STUDY)

SEPTEMBER 1981

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SECTION 1
INTRODUCTION AND SUMMARY

This report describes the MDTSCO/IBM study of packetization of the Spacelab data handling system, including the alternate approaches considered and the supporting rationale. The material presented is the result of a six-month study for the Marshall Space Flight Center (MSFC) to define a practical implementation.

1.1 STUDY BACKGROUND

The coming trend in telemetry systems is toward "packetization" of data. Whereas systems of the past have drawn a single sample from each instrument consecutively and commutated the samples for downlinking, the packet concept devotes an entire downlinking frame or "packet" to each instrument. There are several important advantages to this approach and several reasons why it is becoming more feasible.

An immediate benefit from packets lies in the fact that the task of data stripout on the receiving end is standardized, allowing a user to get his data faster and at less cost. A second advantage is that the capability of the downlink can be more efficiently apportioned among competing data sources. Rather than sampling every instrument on every commutating cycle, data is taken only when a packet is complete.

The pacing technology item which is making the packet concept feasible is the advent of fast, low-cost storage devices such as are possible with large scale integrated circuits and bubble memories. It is becoming practical now to store large quantities of data on-board at the source for the formation of packets. As data processing and storage technology advances, an ever increasing trend toward "smart sensors" and extensive data reduction at the source is inevitable.

In anticipation of the trend toward packetization, the National Aeronautics and Space Administration through its Goddard Space Flight Center (GSFC) developed a proposed standard: Guideline 3.3, Space Data Packetization, Issue 1979-11-05 (ref. 1). The goal is to standardize all space telemetry systems to the packet format so that a common ground facility can process all space telemetry data. Both the Goddard Center and the Jet Propulsion Laboratory are

actively working toward applying packet standards to their future spacecraft . The Marshall Space Flight Center, which is responsible for design and development of the Space Telescope, has specified a packetized system for data handling on this major new satellite.

NASA Headquarters has initiated a comprehensive effort to ascertain how Spacelab can be converted to packet standards and the associated cost. This consists of three concurrent efforts: (1) the Flight System Study by MDTSCO, of which this report is a part; (2) the Ground System Study by Ford Aerospace and Communications Corporation; and (3) the Instrument Study, which is currently an internal NASA effort.

1.2 FLIGHT SYSTEM STUDY

The Flight System Study was a six-month effort initiated in September, 1980, as a modification to MDTSCO's Spacelab Integration Contract. The objective was to determine the most cost effective approach to packetization of Spacelab and to estimate the cost of conversion. The study was limited to the Spacelab flight system, the associated ground support equipment (GSE), prelaunch processing at the Kennedy Space Center (KSC) and the High Rate Demultiplexer (HRDM). Operational ground systems and the flight instruments were excluded, and the costs of packetizing these must be added to the estimates from this study.

Three major ground rules were applied to the flight system study:

(1) Space Data Packetization Guideline 3.3 (Nov. 5, 1979 Issue) was a mandatory guideline for the study.

(2) Spacelab's performance capability was not to be upgraded or downgraded by packetization.

(3) The Orbiter and TDRSS downlink were assumed to be transparent.

The November 5, 1979 issue of Guideline 3.3 was chosen as the basis for the study because it is the most recent version to receive wide acceptance both at GSFC and at NASA Headquarters. Later versions were examined and it is believed that the differences would have no significant effect upon the cost data or conclusions concerning the flight portion of the system. The second ground rule was adopted to ensure that only the cost of packetization is obtained. In the event that Spacelab is actually converted to packet format this ground rule should be suspended to allow consideration of other changes for concurrent implementation.

The Spacelab data handling system is really two systems in one: a system for handling data from low data rate experiments (less than 35 Kb/s) and a different system for high data rate experiments (up to 16 Mb/s). High rate data can be packetized either within Spacelab or the experiment, because Spacelab merely relays high rate data streams transparently to the ground. It is not appropriate to packetize the low rate data within the experiments however, because Spacelab performs certain non-transparent operations on these data streams after they leave the experiments.

Because of the foregoing considerations, it was decided to divide the flight system study into two phases. The first phase assumed Spacelab would be required to have the on-board capability to build data packets for all experiments. The second phase assumed Spacelab would have to build packets only for the low data rate experiments, with the high data rate experiments building their own packets. The two phases were conducted independently of each other.

Phase I occupied the first four months of the study and resulted in the conceptual design of a "full" system capable of packetizing both low and high rate data. The full system is implemented by completely replacing Spacelab's High Rate Multiplexer (HRM) with a "High Rate Packet Multiplexer" (HRPM). The HRPM is a microprocessor based device requiring a three-year development cycle.

Phase II of the study was conducted during the last two months and evolved the conceptual design of a "hybrid" system, which builds packets only for low data rate experiments. Two hybrid options were investigated: (1) performing packetization of low rate data within Spacelab's existing Experiment Computer, or (2) adding a new component called a "Dedicated Low Rate Packetizer" downstream of the Experiment Computer to perform the required operation without disturbing the Experiment Computer. It was determined that the Experiment Computer cannot perform the packetization function because it has insufficient memory and processing speed, and does not have access to the Subsystem Computer data bus. Consequently, addition of the Dedicated Low Rate Packetizer is necessary if Groundrule No. 2 is to be satisfied.

The crude cost analysis performed as a part of the study places the total cost of development of the hybrid systm at $3.3 million as compared with $12.1 million for the full system. These figures include design, development, qual testing and delivery of three flight units and the ground support equipment necessary for prelaunch processing at KSC.

It is the conclusion of the study that, from a technical standpoint, it is well within today's state-of-the-art in microelectronics to implement either the full or hybrid packet data system on board Spacelab. Of the two the hybrid system is preferred because of the significant cost saving. It is further recognized that the hybrid approach can be implemented within the ground based portion of the data handling system with theoretically identical performance, because the Spacelab HRM/HRDM downlink is designed to be transparent (Minimum Impact Approach). The ground based hybrid approach saves the flight qualification costs as well as the costs for two additional flight units, and avoids any weight, volume or electrical power penalty to Spacelab.

Section 2 of this report gives an overview of the concept of packetized data and packet data handling systems. Sections 3 and 4 describe the full and hybrid approaches to the packetization of Spacelab respectively. The study conclusions appear in Section 5. Highlights of the present Spacelab data handling system are included as Appendix A, and the Payload Operations Control Center format standard is reproduced in Appendix B for easy reference. References are given in Appendix C and abbreviations are listed in Appendix D. Appendix E gives a detailed description of KSC support for Spacelab and discusses packetization impacts to it. B

SECTION 2
SPACE DATA PACKETIZATION

Because of the critical importance of data communications to American and international space exploration programs, the National Aeronautics and Space Administration (NASA) is devoting considerable attention to the advancement of space communications and data handling systems. These efforts are converging toward a standardized packet format for all space measurement data, and a common packet handling system. The major goals are to:

- Deliver high quality data products to the user rapidly, efficiently, and inexpensively.
- Permit instruments to acquire and transmit data at an instantaneous rate appropriate for the phenomenon being observed.
  - Adaptively allocate portions of fixed downlink bandwidth.
- Encapsulate, at the source, all the necessary data for the interpretation of a set of experimental observations (provide "data autonomy"):
  - employ a high degree of standardized interfaces, protocols and data structures across missions
  - maintain a constant interface to an instrument throughout its life cycle (bench test, integration, and flight operation).
- Facilitate modular expansion and contraction of capacity without compromising system integrity.
- Provide a data transport process which is transparent to the end user, and which automatically routes data products to their appropriate destinations.
- Provide end-to-end accountabiity and individually tailored error control.
  - automatically monitor quantity, quality, and continuity of data

- provide unambiguous identification of transported data
- allow simple message-billing of users based on resources consumed
- allow a high degree of management visibility.

o Provide a data transport capability which is usable by both near-earth and deep-space missions.

This section will briefly describe the packet format, the packet-handling system and the manner in which the Spacelab data handling system can be embedded into the common system.

2.1 PACKET FORMATTING

A source packet is a well-defined sequence of bits which may correspond to a single observation made by a particular spaceborne instrument. A source packet may contain other kinds of data such as engineering or ancillary data. While it must conform to certain standards in order to be compatible with multi-mission facilities, many of its attributes can be determined by its end consumers in a way that maximizes its intelligibility. The basic structure of a packet is presented in Figure 2-1. It has a header containing control bits, a data set consisting of bits originated by a sensor and a trailer providing error control.

An example of how these segments may be further defined is presented in Figure 2-2, taken from Guideline 3.3 (ref. 1). A packet has a primary header for control and a secondary header containing ancillary data (time, orbit, and/or attitude). The "SOURCE ID" bits unambiguously identify the instrument to which this particular packet is dedicated. The "MISSION ID" serves a similar purpose for the spacecraft carrying that instrument. Since each instrument gives rise to an infinite sequence of packets, the "SOURCE SEQUENCE COUNT" identifies the sequential order of the particular packet. Although this field recycles modulo 2^{16}, two packets bearing the same source count can be distinguished from one another by referring to the time code in the secondary header. The "PACKET LENGTH" field indicates which packet length in a set of canonical packet lengths applies to this particular packet. The "SECONDARY HEADER IDENTIFIER" specifies the types and locations of ancillary data within the secondary header. In

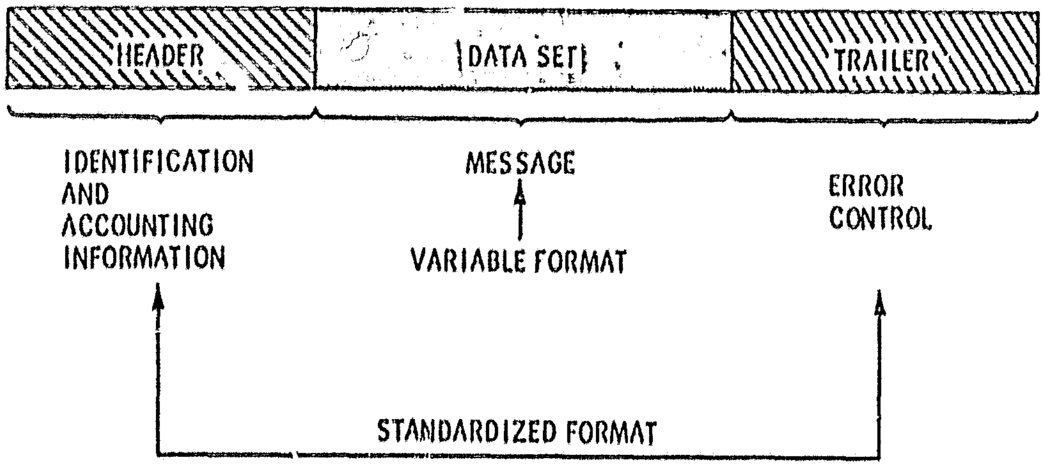


Figure 2-1. PACKET COMPONENTS

PRIMARY HEADER							SECONDARY HEADER	SOURCE DATA	TRAILER
SOURCE ID	MISSION ID	SOURCE SEQUENCE COUNT	PACKET LENGTH	SPARE	SECONDARY HEADER IDENTIFIER	SOURCE ID PARITY			ERROR CONTROL PARITY (OPTIONAL)
8	8	16	8	8	8	8	VARIABLE LENGTH	VARIABLE LENGTH	16

Note: Field sizes shown in bits.

Figure 2-2. SOURCE PACKET FORMAT

order to minimize the probability of a packet being mis-routed, the "SOURCE ID PARITY" field provides an added degree of error control.

Packets may include a short "ERROR CONTROL PARITY" field. Experiments requiring a high degree of error protection are free to employ as many parity bits as necessary.

Ancillary data may be downlinked in either of two ways, depending on the needs of the particular users. It can be placed in the secondary header of a packet along with instrument source data. Alternatively, it can be placed in its own "utility" packet which would be appropriately registered with respect to source packets. If utility packets are used for downlink of ancillary data , it will be necessary to time-correlate source packets with the corresponding utility packets. Interpolation may then be required to adjust the values in the ancillary data to the exact times of the data in the source packets.

The source packet format for each instrument is defined, in conformance with specified requirements, by the end users of the data. This is done during the design phase of the mission. A packet is not subject to processing which deliberately alters the information content of its Source Data. It is conveyed from the spacecraft to its sink(s) and is presented to a sink in the same form as it had when it was generated. A sink may be a professor's terminal, a data base, or some special device. After delivery to the sink, the packet may be subjected to whatever information processing is deemed appropriate.

Downlinked packets may contain instrument data, ancillary data, or engineering data. Some packets may be generated on the ground. For example, a packet may contain link quality statistics from the space-to-ground data acquisition session (which may take from several minutes to a few hours for a satellite or deep space mission). Other packets may be used to transport corollary data from ground instruments, such as a rainfall gauge. Thus, universal data handling facilities can handle all kinds of data.

Packet telemetry is compatible with current telemetry frame standards in that the downlinked bit stream is quantized into frames having sync bits and control headers. However, rather than placing instrument data into fixed word assignments, packet telemetry fills the frames with packet data. The telemetry frame (or

"transport frame") format prescribed by Guideline 3.3 is presented in Figure 2-3. Leading the frame is a header which contains various types of control data. A sync field is followed by the "XMIT MODE ID" which identifies the currently selected options of the telemetry system (e.g., transmission rate, coding mode and multiplexing options). Following this is a "FRAME SEQUENCE COUNT" field which allows reordering of telemetry frames into chronological order if the order is disturbed for some reason. The "FRAME FORMAT" field defines the length of the transport frame along with the number of 16-bit words contained within the "STATUS INSERT" field. The "SEGMENT NUMBER" field identifies how the packet contained within the transport frame is segmented.

The "STATUS INSERT" field provides a means whereby engineering/housekeeping telemetry can be synchronously multiplexed onto the telemetry channel concurrent with the transmission of applications data packets.

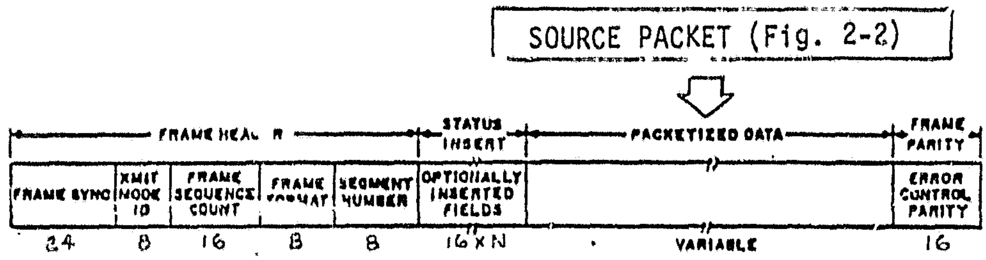
If the mission elects to use variable packet lengths, some packets may be too long to fit wholly within a single transport frame, which is itself of constant length. In such case, the packet may be broken into segments which are downlinked in sequence by a series of transport frames. An example of this process is presented in Figure 2-4. If the mission elects to use a single packet length, each packet is enclosed entirely in one transport frame, with fill bits in the unused portion of the "PACKETIZED DATA" field.

2.2 PACKET-HANDLING SYSTEM

A block diagram of an end-to-end packet data handling system is shown in Figure 2-5. The system consists of spacecraft components, space-to-ground transmission equipment, ground-based data handling elements and user facilities. Source packets originating on board the spacecraft flow through the system, entering the appropriate data bases and arriving at the correct user destinations. Command and control data are uplinked to the spacecraft in a similar way, but at much lower data rates.

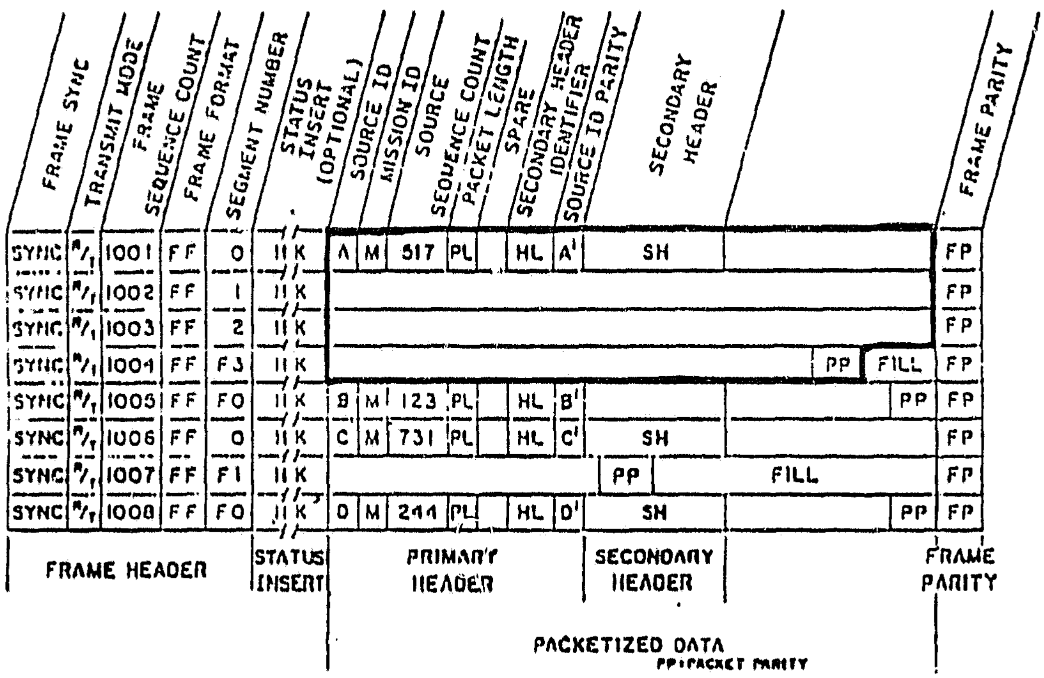
2.2.1 Spacecraft Subsystem

A functional schematic of the spacecraft subsystem is shown in Figure 2-6. Data from the various experiments on the spacecraft and time information are inputs to the Onboard Information Processor. This is a generic function which subjects raw telemetry to preliminary editing, filtering, or transformations. Thus,



Note: Field sizes shown in bits.

Figure 2-3. TRANSPORT FRAME FORMAT



Notes: 1. The source packet from Source ID "A" is heavily outlined.
2. All secondary headers are shown as being the same length; however, this is not a requirement.

Figure 2-4. EXAMPLE OF EMBEDDING SOURCE PACKETS

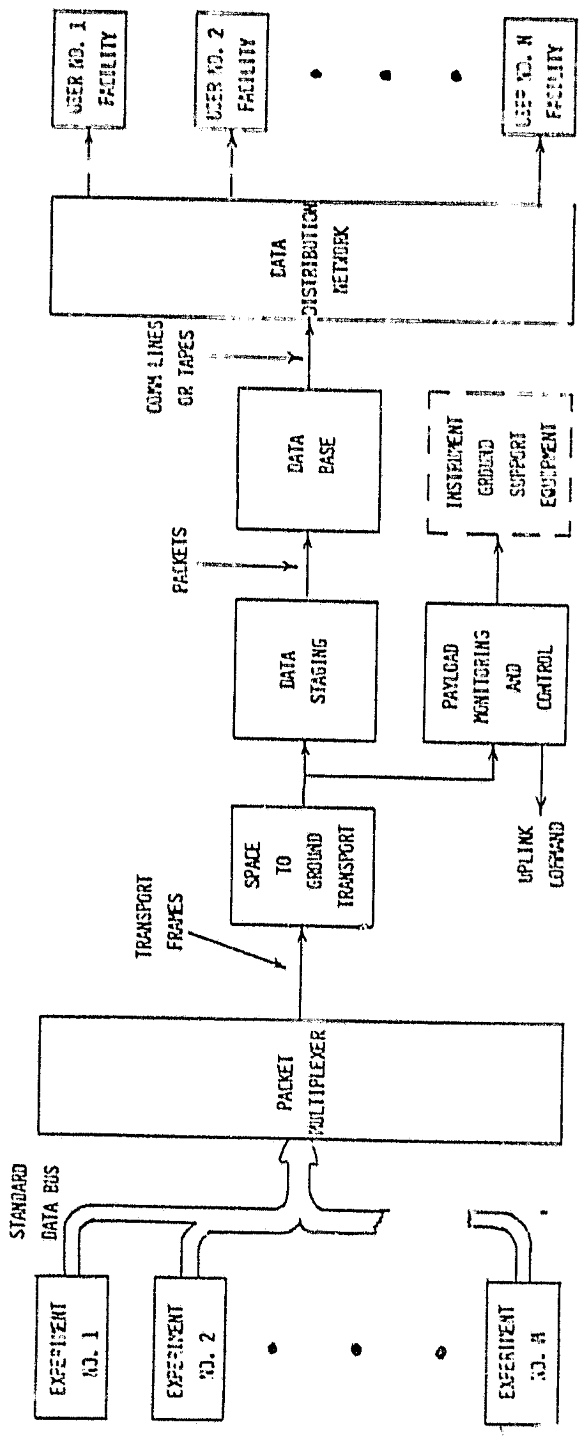


Figure 2-5. END-TO-END PACKET DATA HANDLING SYSTEM

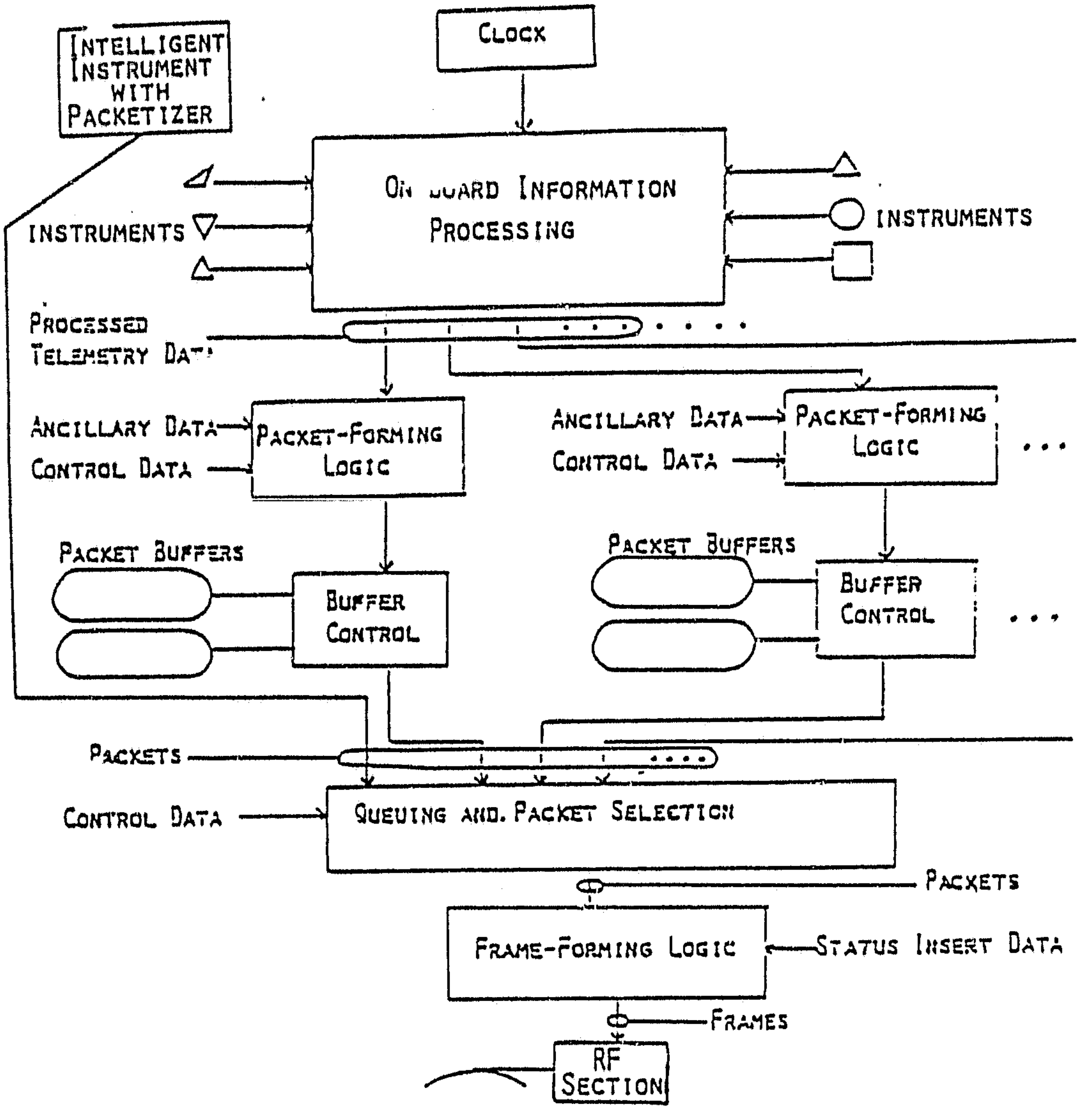


Figure 2-6. A GENERAL SPACECRAFT PACKET DATA SYSTEM

the Onboard Information Processor alters the information content of data, and is not a function geared towards data transport. Since some experiments may require very precise time registration, and since the transformations or other processing performed by the Onboard Information Processor may introduce indeterminate time delays, it is necessary to merge the time and telemetry data streams immediately at the Onboard Informatoin Processor input port. All the instruments on the spacecraft may share the same Onboard Information Processor, or each may have its own.

The workspace used by packet-forming logic is a "packet buffer". Since the frame-forming logic must be prevented from reading a buffer while the packet-forming logic is writing into it, dual buffers are usually required for each instrument. (The exception to this is the case where the instrument can fill a buffer and then wait for the buffer to be emptied prior to beginning to fill it again.) The mechanism for managing these dual buffers is similar to that for controlling the "ping-pong" buffers used in some conventional telemetry systems, since the reading function and the writing function are alternately switched between the two buffers. However, buffer control for packet telemetry is slightly more complicated. This is because it may not always be possible to guarantee that the frame-forming logic will be finished reading from its packet buffer at the same time as the packet-forming logic is finished writing into its packet buffer. The read/write channels must not be switched until both functions using the packet buffers release them. This is unlike the highly synchronized situation in some conventional telemetry systems, where the read/write time intervals are fixed for a particular telemetry format.

Since the packet-forming processes for all the instruments are independent of each other, it is likely that there may be several buffers simultaneously holding completed packets waiting for downlink. Sequential merging of packets into the downlink is accomplished by the Queuing and Packet Selection logic. There are at least two different ways for this function to obtain information about which packet buffers contain completed packets ready for downlink. In one approach, the packet buffer control functions are given the responsibility for actively informing the packet selection function that a packet is ready. This method can be particularly efficient when packets appear infrequently. Another approach is for the packet selection function to actively poll each of the buffer control functions for a

Packet Ready indication. If data from some instruments are more urgent than from others, this can be reflected in the polling schedule by polling some instruments more frequently.

Whichever approach is used, Packet Ready indications will probably be written into a table or queue. This table can be periodically scanned by the packet selection logic. The use of this logic provides a major advantage of packet telemetry: instrument data can be downlinked only when necessary. If an instrument's controller decides that nothing interesting is being observed by that instrument, no packet will be created and therefore no downlink bandwidth will be wasted. When packets do appear, they are downlinked in their turn. Thus, downlink bandwidth can be allocated adaptively among the instruments on board on the basis of their current data transfer requirements by the queuing and packet selection logic.

2.2.2 Space-to-Ground Link

Within the spacecraft, transport frames are passed to a communications device which converts them to radio signals for transmission to earth. Transmission may be directly from the spacecraft to the ground station, or it may go through the Tracking and Data Relay Satellite System (TDRSS). Telemetry packets are viewed by space-to-earth transmission processes merely as a stream of bits requiring reliable transport. The processes are therefore transparent to packets. At the receiver, bit synchronization and transport frame synchronization retain the traditional roles of locating bit and bit field boundaries.

Due to the use of fixed transport frame lengths the receiver enjoys the advantages of a sync pattern appearing at a known fixed interval. The output of the space-to-ground segment is a sequence of synchronized transport frames.

2.2.3 Ground-Based Elements

Once transport frames have been received on the ground, source packets must be re-assembled, accounted for, and sent on their way to the end users. These functions are performed by the Data Staging Facility and the Data Transmission Network (Figure 2-5).

Packet re-assembly is achieved using information contained in the transport frame headers. If segments of a long packet have been embedded within a sequence of transport frames, the SEGMENT NUMBER COUNT fields in the headers of those frames permits the successive reconstitution of the original packet. At the end of the packet re-assembly process,the transport frame protocol has been stripped

away, and a stream of whole packets is produced. This process is accomplished automatically under computer control by a facility which may be shared by many missions. The adherence by those missions to format standards permits this generalized facility to successfully and inexpensively process their telemetry.

In spite of the use of error control measures, packets with bit errors or missing segments are certain to appear. The disposition of such packets is a matter of mission policy. Some experimenters may wish to see packets even if they are known to contain errors. Such packets would be flagged and sent on. If erroneous packets are not desired, they would be logged and then discarded.

Other data staging functions may be performed at the ground station, or at some other centralized or decentralized NASA facility. In the latter case, a data communication network must provide an online connection between the ground station and the other facility. Data staging may include the following functions:

- Provision of a short term (approximately 48 hours) data base.
- Reversal of bits received from playback of a spaceborne tape recorder.
- Deletion of redundant data.
- Conversion of incoming data rate to match capacity of the out-going data transmission network.
- Conversion of data cataloging from a mission/data acquisition session basis to a user's time line basis.
- Sorting of incoming telemetry packets into individual instrument data sets.
- Creation of user data sets which may include telemetry packets for a specialized user, accounting and quality control information, and possibly copies of other user's telemetry packets.
- Identification of "holes" in data sets caused by missing packets.

"Store and Forward" may be a mode of operation in data staging for some

missions. Packets are gathered from the data acquisition network, some or all of the functions listed above are performed, and periodically, by an agreed-to schedule, the user data sets are generated and output to the data transmission network.

Another responsibility of data staging relates to the transmission of data sets to their end consumers. It is likely that many of these users will require an online connection to data staging. The communications network providing such connections will establish a node ID for each user. Since the Mission ID and Source ID in the header of a telemetry packet would be meaningless to this network, data staging must maintain a table indicating which users are to receive data sets from which instrument. The table will be a set of correspondences between Mission/Source ID's and node ID's. As data staging turns over each data set (and perhaps multiple copies of a data set) to the data transmission newtork, it must affix a destination code which is understandable by the network. This process is accomplished automatically.

Online connections are required between the ground station and the Data Staging Facility, and also between the Data Staging Facility and primary destinations of data sets. The types of links selected, be they wire, terrestrial microwave or domestic communications satellite, correspond to the particular data transfer requirements of each connection. These links may be leased lines, commercial (value added) networks or a combination during peak traffic periods or for direct transmission to smaller users. To the extent feasible, this network will employ packet switching under international standard protocols such as X.25. In cases of very high bit rates, circuit switching may be employed instead.

It is important to distinguish between telemetry packets and communications packets. Just as the transport frame format is optimized for conditions encountered in the downlink, communications packets are optimized for a terrestrial network. A sequence of telemetry packets is viewed by the terrestrial network merely as a bit stream requiring transport. This stream will be segmented in an arbitrary manner, placed into communications packets, carried to the destination, and re-assembled into its original form. Since the packet switching network is self-managed and accomplishes its own routing and error control, it is transparent to its users.

It is also important to distinguish between primary data sinks and other sinks. Primary data sinks are data bases, control centers and certain online real-time

users. Dissemination of data products from these primary sinks to other consumers is accomplished by a data distributior network. It is recognized that for end users not having an urgent need for rapid delivery of data, magnetic tapes may be the most cost-effective means of data transmission. The packetized format is preserved by magnetic tape.

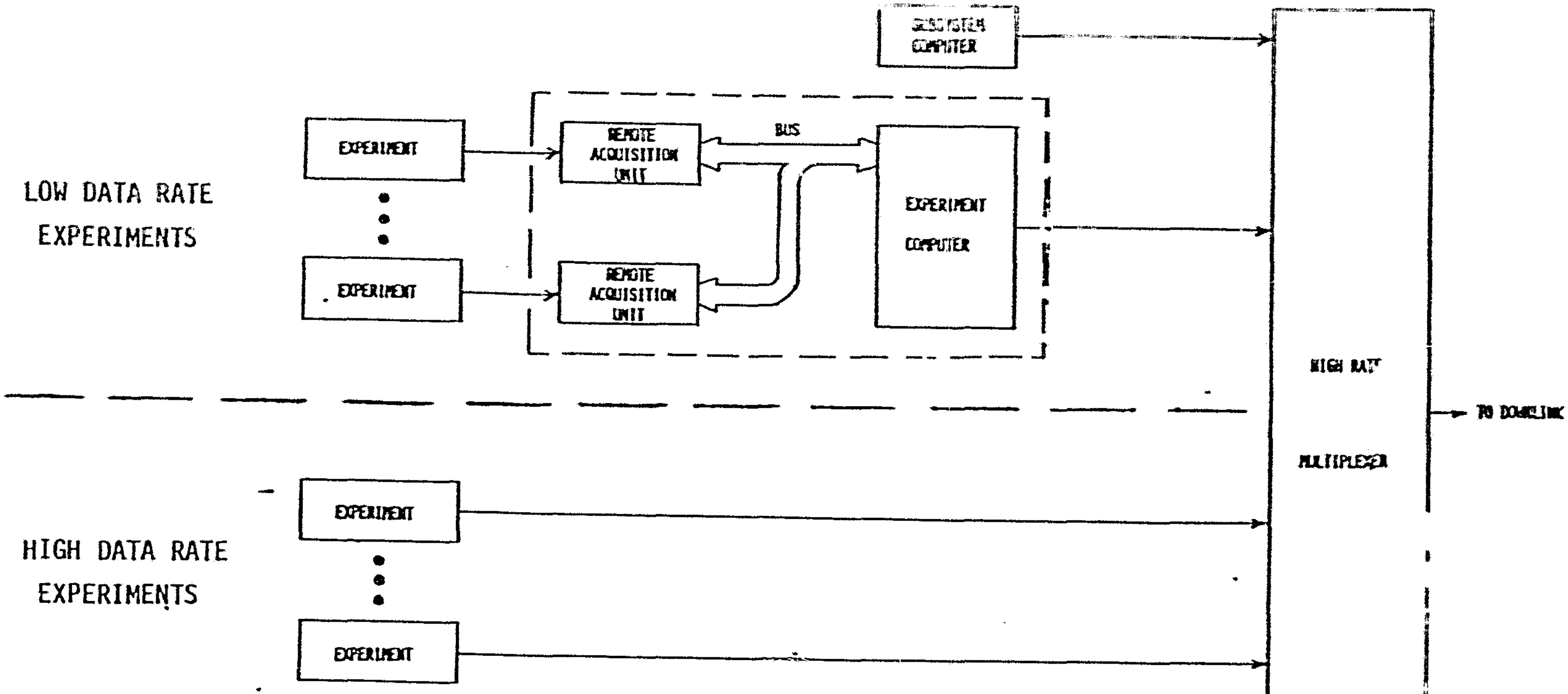
2.3 CONVERSION . SPACELAB TO PACKET FORMAT

It would be straightforward today to design Spacelab to be compatible with packet standards. However, the design of both the flight and ground portions of the Spacelab data handling system pre-date packet formats by several years. Consequently, the issue at this point is how to gain the maximum benefit from packetization of Spacelab with an acceptable impact to the tremendous investment already made in the existing system.

The Spacelab data handling system can be divided into two different parts: a low data rate section and a high data rate section (Figure 2-7). The low data rate section acquires experiment data via Remote Acquisition Units (RAU's) which pass the data to the Experiment Computer via a common data bus (See Appendix A for a more detailed description.) The RAU's and Experiment Computer perform certain non-transparent operations on the data (e.g., analog-to-digital conversion, on board display, etc.), in addition to multiplexing with housekeeping data for downlink on a common channel (the ECIO channel).

Because of the dual nature of the Spacelab system it was decided to divide the study into two phases. The first phase was based on the premise that Spacelab must have the capability to packetize all experiment data. In the second phase it was assumed that the high rate experiments would be able to packetize their own data; consequently, Spacelab would packetize only the low rate data acquired via the RAU's. These two phases resulted in the defintion of two distinct design approaches: the so-called "full" system and the "hybrid" system.

The full system approach assumes that a multi-spacecraft packet data handling system already exists on the ground, and that Spacelab is modified to interface with it it (Figure 2-8). The modification consists of replacing the High Rate Multiplexer" (HRM) with a "High Rate Packet Multiplexer" (HRPM) which completely synthesizes packets on board. The HRPM delivers a transport frame stream to the downlink which complies totally with Guideline 3.3. On the ground



DATA HANDLING SERVICES

- o LOW RATE DATA: On-Board Display
  Limit Checks, etc.
  TDM Downlink
- o HIGH RATE DATA: Transparent Downlink

Figure 2-7. SPACELAB DATA HANDLING FEATURES

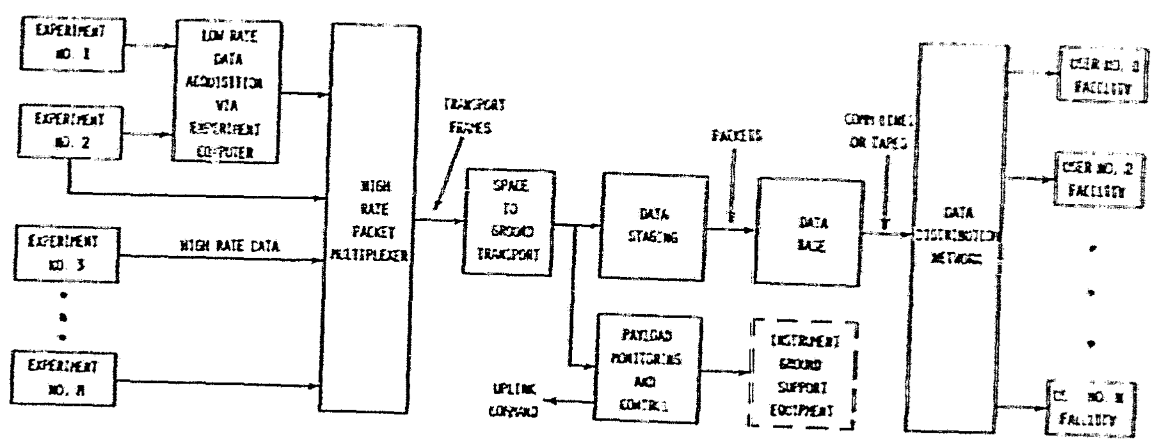


Figure 2-8. END-TO-END "FULL" SYSTEM

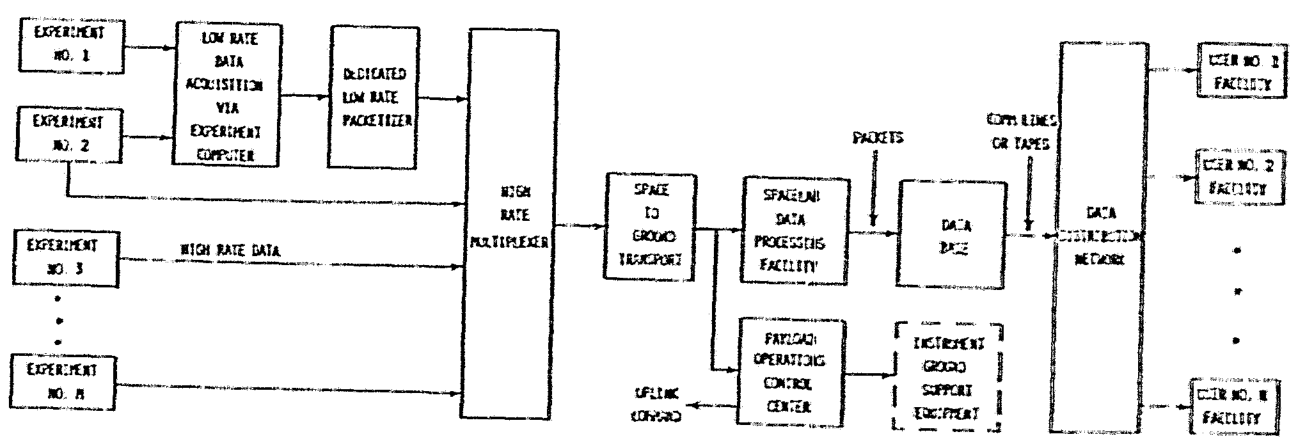


Figure 2-9. END-TO-END "HYBRID" SYSTEM

common data processing facilities handle data packets from Spacelab as well as packets from other compatible spacecraft. These facilities perform all necessary data handling functions including near real time display for payload monitoring and control, connections for User IGSE, and processing and delivery of data products. Operational costs of the common facilities are billed to individual users (including Spacelab) according to a rate schedule of the services rendered.

The second approach, the "hybrid" system, assumes that all high data rate experiments form their own packets and that the existing HRM-HRDM downlink can be used as is to relay these packets to the ground. The only modification to the Spacelab flight system is the insertion of a "Dedicated Low Rate Packetizer" to packetize low rate data entering Spacelab via RAU's (Figure 2-9). On the ground the POCC and SLDPF are maintained intact with the following changes. The POCC is modified to display data from packet formats and the SLDPF is modified to interface with a common packet data staging and distribution system.

It should be noted that, as a part of the flight system study, packet data formats were defined at the flight/ground system interface for both the full and hybrid approaches. This was done so that the flight system could be sufficiently defined to prove technical feasibility and permit estimation of the cost of conversion. The formats are believed to be reasonable, but they should in no way be considered binding upon the ground and expeirment studies. The formats recommended by the ground study will be assessed for impact upon flight system and KSC costs, and if warranted, the cost estimates adjusted accordingly.

SECTION 3
ᵀULL SYSTEM

3.1 OVERVIEW

This section briefly describes the full packet data system for Spacelab, the design rationale, anᵈ ᵗhe estimated development schedule. Cost data are provided in Section 5. The full system concept was first presented at the Packet Data Conference held at the Marshall Space Flight Center on 21-22 January 1981. As a result of that conference the following clarifications and changes were agreed upon:

(1) Spacelab will contain no reversing logic for data from High Data Rate Recorder (HDRR).

(2) Transport frame format will contain a time code in the "STATUS INSERT" field.

(3) Multiple length packets are permitted on high rate channels, provided they have valiᵈ sync patterns and lengths.

(4) The transport frame length is a mission choice and can be any value up to 512 words (8192 bits).

(5) The HRPM performs ECIO decommutation and packetization.

Figure 3-1 shows an overall block diagram of the full packet data system. All features of the existing system (Figure A-3) are retained, with the exception that the HRM sampling switch is replaced by the High Rate Packet Multiplexer (HRPM). Interfaces to the payload and to the Orbiter are identical. The requirements for the HRPM are summarized as follows:

16 Experiment Channels	-	Max Channel rate 16 Mb/s
2 Direct Access Channels	-	Max Channel rate 50 Mb/s
2 CDMS Computer Channels	-	25.6 Kb/s and 51.2 Kb/s
3 Voice Channels	-	128 Kb/s
1 PLR Playback	-	1 Mb/s
1 HDRR Playback	-	2, 4, 8, 12, 16, 24, or 32 Mb/s

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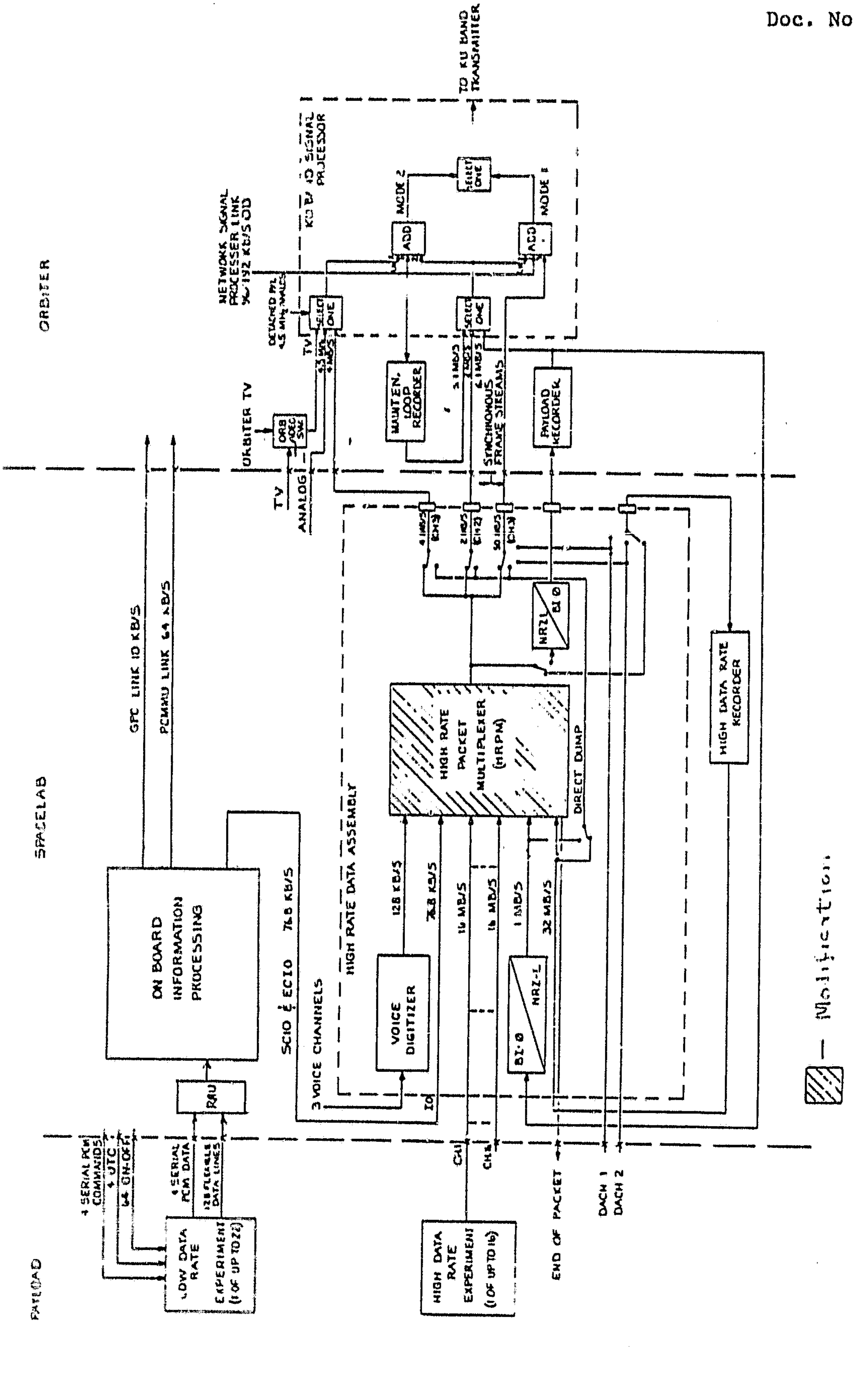


Figure 3-1. FULL PACKET DATA SYSTEM FOR SPACELAB

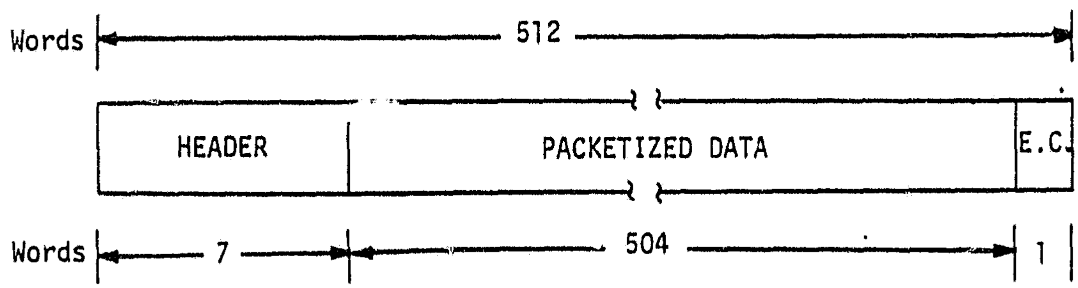
The header is made up of five fields: A 24-bit synchronization pattern, an 8-bit "FRAME ID" field, an 8-bit packet segment counter, a 16-bit "FRAME COUNT", and a "STATUS INSERT" field. Th synchronization pattern is a fixed code for all Spacelab missions, selected to have a good autocorrelation value. The probable number is 75121314 octal, MSB first.

The "FRAME ID" field is an 8-bit code which identifies Spacelab as the originator of the transport frame. The ID is assigned by the agency operating the ground network responsible for capturing the data, and its primary purpose is to infer the format of the transport frame. A secondary purpose for this field is to identify the type of data carried by the transport frame: live data, previously recorded data, fill bits, or DACH data. The bit positions and codes used for data type identification are TBD.

The packet segment counter indicates which segment of the packet is contained in the data field of the transport frame and how many segments the packet consists of all together. (See subsection 3.2.2 for a discussion of packet segmentation). The "FRAME COUNT" field is a modulo 2^{24} counter which increments once for each new frame being downlinked. This field is used on the ground to make sure that frames are received in the order sent and to detect missing frames. The counter together with the time code in the STATUS INSERT is also useful in identifying where "FRAMES" previously recorded on board Spacelab should be inserted into the live data stream. The "STATUS INSERT" field contains the Coordinated Universal Time in IRIG B format at which the frame was output from the HRPM for downlinking or recording.

The "PACKETIZED DATA" field contains source packets or fill bits as described in subsections 3.2.2 and 3.4.1 respectively. There are no restrictions on this field except that the 24-bit synchronization pattern must not appear periodically within the data field. (It is acceptable for it to occasionally appear randomly). A 16-bit cyclic redundancy code (CRC) can be added at the end of the frame for error control if desired.

The length of the transport frame is set during the planning phase of a mission and cannot be changed during the mission. The maximum length is 512 words (8192 bits). The data field efficiency for the maximum length frame is 98.4%, as shown in Figure 3-3. Shorter frame lengths lower the efficiency.



Data Efficiency = $\frac{504}{512}$ = 98.4%

FIGURE 3-3. DATA EFFICIENCY FOR MAXIMUM LENGTH TRANSPORT FRAME

3.2.2 Source Packets

The source packet format selected for use in the full Spacelab packet data system is in full compliance with Guideline 3.3 (See Figure 2-2).

The length of the source packet can be any integral number of 16-bit words allowed by Guideline 3.3, provided it does not require more than 16 transport frames. The maximum allowable length of source packet will depend upon the transport frame length chosen for the mission. For example, if the maximum frame length of 512 words is chosen, the maximum packet length is the usable data field length per frame (504 words) times the maximum number of frames per packet (16). This results in a maximum allowable packet length of 504 x 16 = 8064 words or 129,024 bits. Table 3-1 lists all the packet lengths allowed by Guideline 3.3 (Table 3.3.2) which do not exceed 129,024 bits.

Five types of source packets are produced by Spacelab: Voice packets, Subsystem Computer Input/Output (SCIO) utility packets, Experiment Computer

Table 3-1. ALLOWABLE SOURCE PACKET LENGTHS FOR SPACELAB

CODE (HEX)	LENGTH (WDS)	CODE (HEX)	LENGTH (WDS)	CODE (HEX)	LENGTH (WDS)	CODE (HEX)	LENGTH (WDS)	CODE (HEX)	LENGTH (WDS)
00	8	28	48	48	192	68	768	88	3072
02	9	29	50	49	200	69	800	89	3200
04	10	2A	52	4A	208	6A	832	8A	3328
06	11	2B	54	4B	216	6B	864	8B	3456
08	12	2C	56	4C	224	6C	896	8C	3584
0A	13	2D	58	4D	232	6D	928	8D	3712
0C	14	2E	60	4E	240	6E	960	8E	3840
0E	15	2F	62	4F	248	6F	992	8F	3968
10	16	30	64	50	256	70	1024	90	4096
11	17	31	68	51	272	71	1088	91	4352
12	18	32	72	52	288	72	1152	92	4608
13	19	33	76	53	304	73	1216	93	4864
14	20	34	80	54	320	74	1280	94	5120
15	21	35	84	55	336	75	1344	95	5376
16	22	36	88	56	352	76	1408	96	5632
17	23	37	92	57	368	77	1472	97	5888
18	24	38	96	58	384	78	1536	98	6144
19	25	39	100	59	400	79	1600	99	6400
1A	26	3A	104	5A	416	7A	1664	9A	6656
1B	27	3B	108	5B	432	7B	1728	9B	6912
1C	28	3C	112	5C	448	7C	1792	9C	7168
1D	29	3D	116	5D	464	7D	1856	9D	7424
1E	30	3E	120	5E	480	7E	1920	9E	7680
1F	31	3F	124	5F	496	7F	1984	9F	7936
20	32	40	128	60	512	80	2048		
21	34	41	136	61	544	81	2178		
22	36	42	144	62	576	82	2304		
23	38	43	152	63	608	83	2432		
24	40	44	160	64	640	84	2560		
25	42	45	168	65	672	85	2688		
26	44	46	176	66	704	86	2816		
27	46	47	184	67	736	87	2944		

NOTES: 1. Lengths are given in terms of 16-bit words

2. Length codes are given in 2-digit (8-bit) hexadecimal code. The two digits are "E" and "M" respectively in the following formula:

$$L = (128 + 8M) \times 2^E \quad = \text{Packet Length in bits.}$$

Input/Output (ECIO) utility packets, low rate experiment packets, and high rate experiment packets.

3.2.2.1 Voice Packets

The HRPM accommodates three analog voice channels coming from the Spacelab Intercom Master Station in the module configuration and, if required, from the Orbiter Audio Central Control Unit (ACCU) in pallet-only configurations. A voice digitizer converts each analog voice signal to a 32 Kb/s digital signal using delta modulation. Each digitizer circuit transmits 4 parallel bits at a sampling frequency of 8KHz (Figure 3-4). If a "CHANNEL ON/OFF" control line is in the "ON" state, packets are synthesized for that channel and inserted into the packet switch queue for downlinking. The packet length is 32,768 bits (length code 80 in Table 3-1), resulting in the generation of one packet per second per voice channel. Each voice channel produces a packet with a unique Source ID so that voice data can be distributed to all interested experimenters by the ground distribution network. The

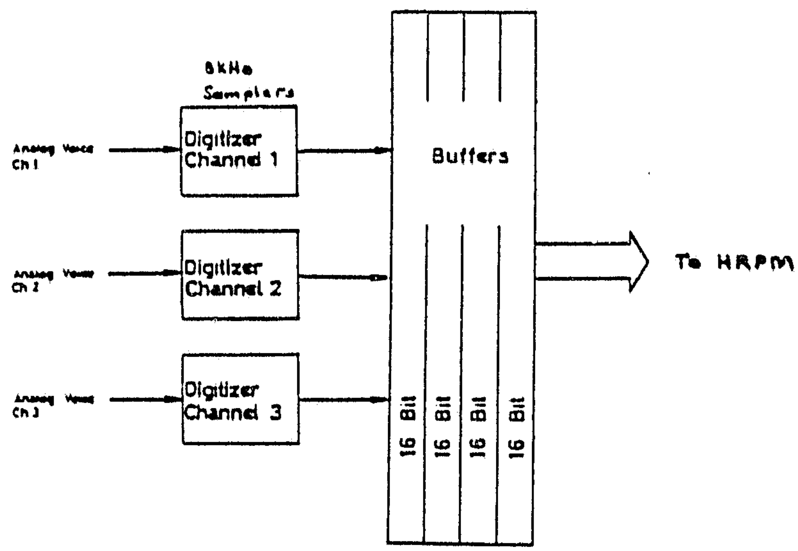


Figure 3-4. VOICE PACKET GENERATION

secondary header contains only a time tag indicating the time at which the packet was synthesized.

Two features should be considered in voice packetization for Spacelab to improve the capability of the present system. They are in-flight changes of Source ID, and voice operated keying. The first allows routing of packets to different destinations on the ground as a function of the mission timeline, and the latter suppresses downlinking of unmodulated packets.

3.2.2.2 SCIO Utility Packets

The subsystem computer transfers blocks of 80 words 20 times a second to the HRM, completing the 1600 word frame shown in Figure 3-5 once each second. When overhead is subtracted there are approximately 1300 words of usable data per SCIO frame. The packet length is chosen at 1472 words (length code 77 in Table 3-1), resulting in the generation of one SCIO utility packet each second.

The SCIO utility packet has a unique source ID which is the same for all missions. The secondary header contains a time tag and the Orbiter state vector. The packet does not contain error control parity. The positions of variables within the SCIO frame and therefore within the source packet data field are mission dependent because of mission-to-mission reconfiguration of Spacelab.

3.2.2.3 ECIO Utility Packets

The Experiment Computer transfers a 160-word minor frame 20 times per second to the HRM, completing the 3200 word frame shown in Figure 3-6 once per second. The frame can be divided into three parts: Overhead, 200 words; PCMMU downlink redundant data, 1100 words; and low rate experiment data, 1900 words. In the packetized system the ECIO frame is divided into two kinds of packets, the PCMMU portion which becomes the ECIO utility packet, and the low rate experiment portion which is discussed in the next subsection. A length of 1280 words (length code 74 in Table 3-1) is chosen for the ECIO utility packet, resulting in the generation of one packet per second. The packet has a unique source ID which remains unchanged from mission to mission. The secondary header contains a time tag and the Orbiter state vector, and the packet carries no error code.

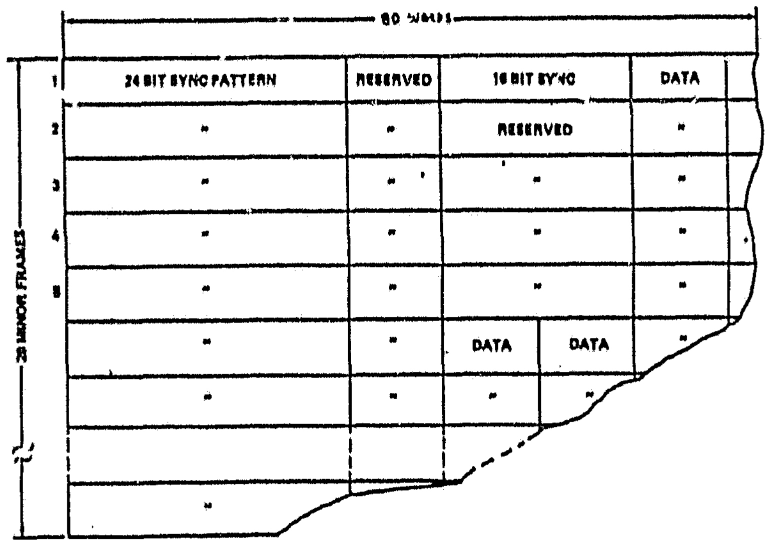


Figure 3-5. SUBSYSTEM COMPUTER FORMAT, TO THE HRM (25.6kb/s)

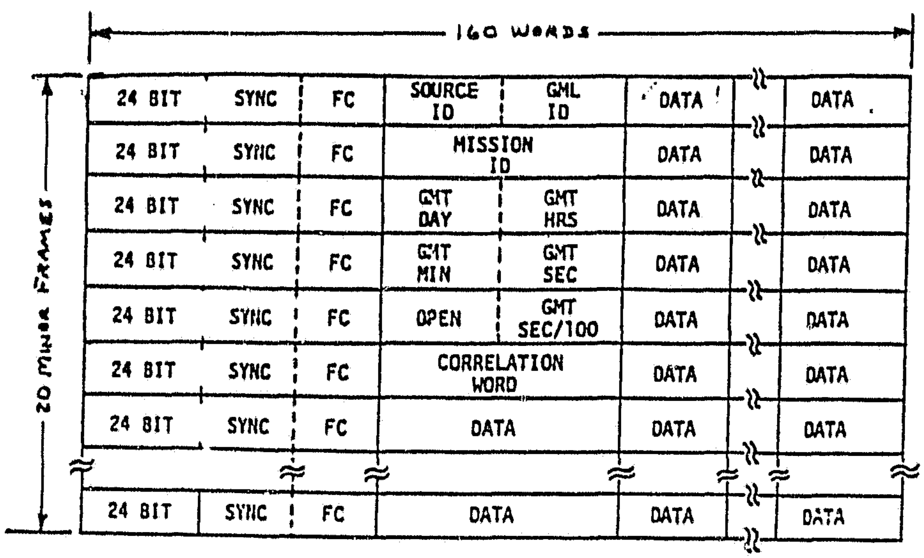


Figure 3-6. EXPERIMENT COMPUTER FORMAT TO THE HRM (51. 2kb/s)

3.2.2.4 Low Rate Experiments

The low rate experiment data portion of the ECIO is decommutated and encapsulated into packets of various lengths for the various low rate experiments by the HRPM. These packets have unique source ID's and secondary headers. The data format is of course mission dependent with the attendant mission unique HRPM software.

3.2.2.5 High Rate Experiments

The Spacelab packet data handling system offers 16 parallel channels to high rate users (16 Mb/s/channel maximum). Each of these channels which is used in a given mission for raw measurement data is allocated a packet length of the user's choice from Table 3-1, and a unique source ID. The contents of the secondary header and source data fields are at the discretion of the user, within Spacelab constraints. Each channel which is used for experiment-originated packets can accept multiple-length packets, provided they are separated by sync patterns and have valid lengths.

3.2.3 Ancillary Data

The Spacelab Packet Data System synthesizes a secondary header within each source packet which it generates, for the purpose of encapsulating ancillary data. As a minimum, the secondary header contains a time tag indicating the time at which the final data word for that packet was received from the experiment. In addition, the user may specify as ancillary data for his packet, any data from the SCIO and ECIO. As with the time tag, these additional ancillary data items normally are read immediately after the final data word is received from the experiment. A certain time skew is inherent in the sampling of ancillary data, and the user should take this into account in specifying the sampling order. Parameters not in the IO lists cannot be specified as ancillary data.

The ECIO contains measurement data from low-rate experiments, and in some instances an experimenter may desire certain measurements from another experiment to be incorporated into his source packets as ancillary data (e.g., the horizon detector on Mission 1). This requirement can be met by the full system from a technical standpoint. However, permission to do so must be granted by the owner of the instrument generating the data.

In the case where a sophisticated experiment builds its own packets, the experiment is responsible for encapsulation of any required ancillary data. While

experiments are provided with time code, the SCIO and ECIO buses are not available to experiments.

A user may speciry as long as a list of ancillary data as he desires. However, he should realize that the more ancillary data he uses the more downlink bandwidth he must have in order to downlink the same measurement data rate. The Secondary Header format codes and ancillary data format are TBD.

3.2.4 Embedding of Source Packets

Source packets are embedded within transport frames according to the following rules, in accordance with Guideline 3.3. A typical sequence of transport frames is shown in Figure 3-7.

1. When the system is ready to downlink a new source packet, the "FRAME COUNT" field of the next available transport frame is incremented by one and the "SEGMENT NO," field is reset.

2. If the source packet is shorter than the "PACKETIZED DATA" field, the remainder of the field is completed with the fill bit pattern, such that overall length of the transport frame is maintained at the constant presetting for the mission.

3. If the source packet is longer than the "PACKETIZED DATA" field, the excess is carried forward to the next transport frame and the "SEGMENT NO." counter is incremented. This segmentation process is repeated until the entire packet has been embedded within consecutive transport frames (16 maximum).

4. When no source packets are available for downlinking, the "PACKETIZED DATA" field of each transport frame is loaded with the "fill bit pattern".

5. Transport frames containing consecutive segments of a packet must be downlinked consecutively. Other transport frames cannot be interleaved until the last packet segment has been transmitted.

FRAME SYNCH.	FRAME I.D.	SEGMENT NO.	FRAME COUNT	STATUS INSERT	SOURCE I.D.	MISSION I.D.	SOURCE SEQUENCE COUNT	PACKET LENGTH	SPARE	SECONDARY HEADER I.D.	SOURCE I.D. PARITY	SECONDARY HEADER	SOURCE DATA
SYNCH	L	1/3	1001	TIME	A	SL6	517	LA		HA	A'	AD	
SYNCH	L	2/3	1002	TIME	SD								
SYNCH	L	3/3	1003	TIME	SD								PP FILL
SYNCH	L	1/1	1004	TIME	B	SL6	123	LB		HD	B'	AD	PP
SYNCH	L	1/1	1005	TIME	C	SL6	734	LC		HC	C'	AD	FILL
SYNCH	P	1/1	1006	TIME	REVERSE BIT STREAM FROM HDRR								
SYNCH	P	1/1	1007	TIME	REVERSE BIT STREAM FROM HDRR								
SYNCH	F	1/1	1008	TIME	FILL								
				TIME									
				TIME									
				TIME									

NOTES: 1. THE SOURCE PACKET FROM SOURCE I.D. "A" IS HEAVILY OUTLINED.
2. SECONDARY HEADERS NEED NOT BE THE SAME LENGTH.
3. FRAME I.D. SYMBOLS ARE: L-LIVE, P-PLAYBACK, F-FILL BITS.

Figure 3-7. TYPICAL EMBEDDING OF SOURCE PACKETS WITHIN TRANSPORT FRAMES

3.2.5 Packet Data Efficiency

Packet data efficiency is defined as the percentage of bits in the downlinked stream of transport frames actually devoted to source data (ancillary as well as measurement data). This number is dependent upon the transport frame length chosen for the mission, the mix of packet lengths and the ratio of fill frames to data frames. If we assume that the transport frame length is 512 words, that all packets are the maximum length of 7936 words (code 9F from Table 3-1) and that there are no fill frames, the efficiency may be calculated as follows:

$$\text{Efficiency} = \frac{\text{Useful Data Words}}{\text{Total Frame Words}}$$

$$= \frac{\text{Packet Length - Packet Overhead}}{\text{Frame Length X Frames/Packet}}$$

$$= \frac{7936 - 5}{512 \text{ X } 16} = \frac{7931 \text{ Words}}{8192 \text{ Words}}$$

$$= 96.8\%$$

3.2.6 Deviations from Guideline 3.3

The formats outlined in Section 3.2 deviate from Guideline 3.3 to the extent shown in Table 3-2. The rationale for these deviations is also given in the table.

3.3 DESIGN DESCRIPTION

The HRPM utilizes microprocessor (μP) design concepts to assemble asynchronously-arriving input data into standard packet data format and to control the downlink sequencing of completed packets. Although various logic units exercise some memory sequencing autonomy, the overall implementation is that of the multi-microprocessor configuration shown in Figure 3-8. The input channels labeled SCIO and ECIO are flexible CDMS computer to HRPM links. Initial Program Load (IPL), operating time, HRPM commands, subsystem status, RAU derived experiment data and Orbiter GPC via EC data are examples of the transfers.

The other inputs do not require the extensive processing associated with the computer link. However, each channel has its own asynchronous serial-to-parallel interface. Parallel data bus transfers route data between a channel interface, its assigned packet buffer and the bit serializer, upon control processor command.

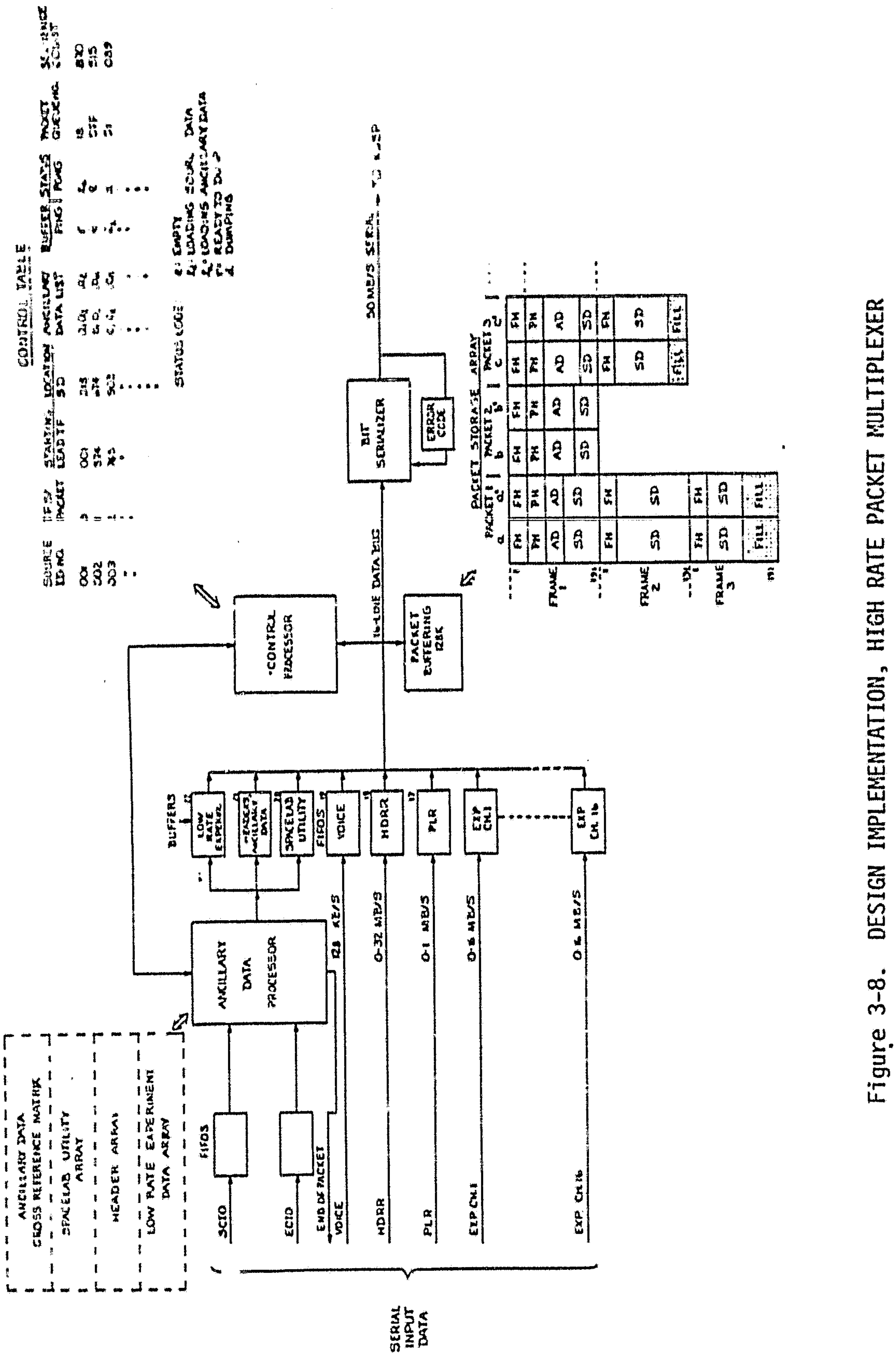


Figure 3-8. DESIGN IMPLEMENTATION, HIGH RATE PACKET MULTIPLEXER

Table 3-2. DEVIATIONS FROM GUIDELINE 3.3

DEVIATION	RATIONALE
o PACKET FORMAT	
• NO DEVIATION	
o TRANSPORT FRAME FORMAT	
• "DATA TYPE" FLAGS ADDED TO "TRANSMIT MODE ID" FIELD. NAME CHANGED.	• PERMITS DETECTION OF LIVE, RECORDED AND FILL DATA FOR MORE EFFICIENT GROUND PROCESSING.
• "FRAME SEQUENCE COUNT" IS INCREASED TO 24 BITS.	• COUNTER RECYCLES LESS OFTEN MAKING IT EASIER TO FIND HDRR OVERLAPS.
• "FRAME FORMAT" FIELD DELETED.	• NOT NEEDED IN SPACELAB BECAUSE FRAME LENGTH IS FIXED THROUGHOUT A MISSION.
• "SEGMENT NO." FIELD SHOWS TOTAL NUMBER OF FRAMES IN PACKET RATHER THAN "LAST SEGMENT" FLAG.	• NUMBER OF FRAMES IN PACKET IS NEEDED FOR MANIPULATION OF ECIO DATA.

3.3.1 INPUT Management

Data arriving at an input channel will be sequentially stored in the data field of that channel's assigned packet image currently designated for "INPUT". The transport frame header, the packet header and the designated ancillary data will also be required, to assemble a complete downlink packet message. The completed packet's memory image is then designated for "OUTPUT" and its companion packet image changes its designation from "OUTPUT" to "INPUT". When packet images are available for downlink, downlink must be accomplished during their OUTPUT designation. A memory image of a typical packet as it attains OUTPUT designation and is queued for downlink is shown in Figure 3-9. Notice that packet lengths requiring multiple transport frames have the transport frame headers residing within the packet's memory image.

3.3.2 OUTPUT Management

As packet images attain OUTPUT designation they are placed in the downlink queue. The lowest downlink queue position always designates a section of memory containing an easily identified fill frame. The sole purpose of the fill frame is to maintain continuous downlink synchronization in the absence of transmittable packets. Fill frames are recognized and discarded at the last downlink synchronizing element.

The higher priority downlink queue positions contain packet transmission

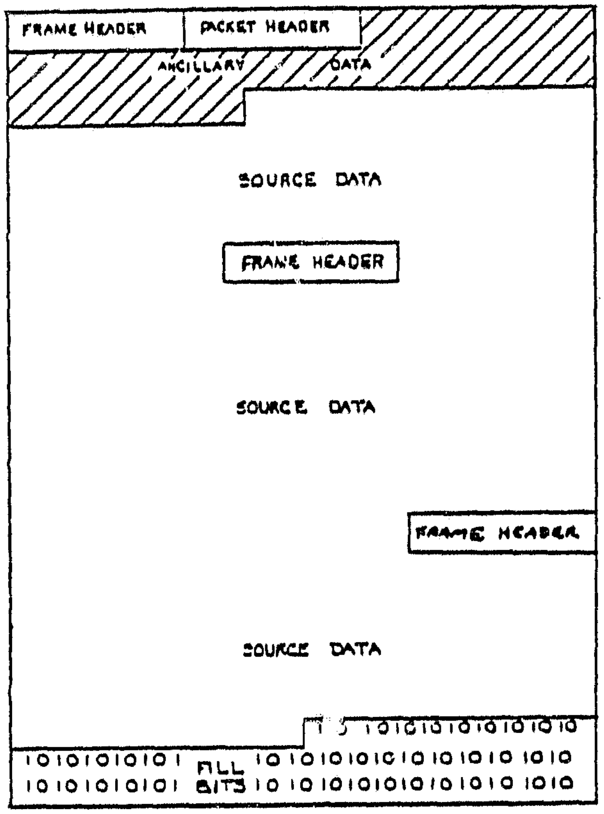


Figure 3-9. PACKET IMAGE IN MEMORY

sequence pointers based on nominal data rates, packet lengths, and on an adaptive algorithm. The adaptive algorithm weights the current polling sequence with recent polling history. Sequencing data into the bit serializer output stream at a rate capable of maintaining the selected downlink bit rate is accomplished at the highest data management priority. All input channels are scheduled or enabled to eliminate resource contending with the bit serializer input. Transport headers and packet headers are mostly "static" data loaded into HRPM memory at IPL. Sequence count fields of the headers will require updating. Ancillary data necessary to complete a packet's memory image require more extensive and dynamic data management.

Ancillary data variables are extracted from the ECIO and SCIO data streams and placed in a memory array. The memory array is the shopping list for all ancillary data. Extracting identifiable ancillary variable values from the ECIO 3200-word format shown in Figure 3-6 and routing each word (or bit) for the low rate field

3 Output ports selectable under program control

1 GMT Time Code

o Plug compatible with HRM

o Existing Spacelab power

The HRPM can accept raw measurement data or finished packets from the experiments. Packets from the experiment channels are merged with those from the voice digitizer and the recorders for downlinking or recording. Ancillary data can be placed in the packet by the experiment or by the HRPM. The output packet stream meets Guideline 3.3, and can be delivered to any KUSP or recorder input port.

3.2 FORMATS

3.2.1 Transport Frame

The format for the transport frame (Figure 3-2) consists of a 112-bit (7-word) header followed by the packetized data field. This format complies with Guideline 3.3, but is a minimum overhead format designed explicitly to satisfy Spacelab data handling needs.

SPACELAB TRANSPORT FRAME DIAGRAM

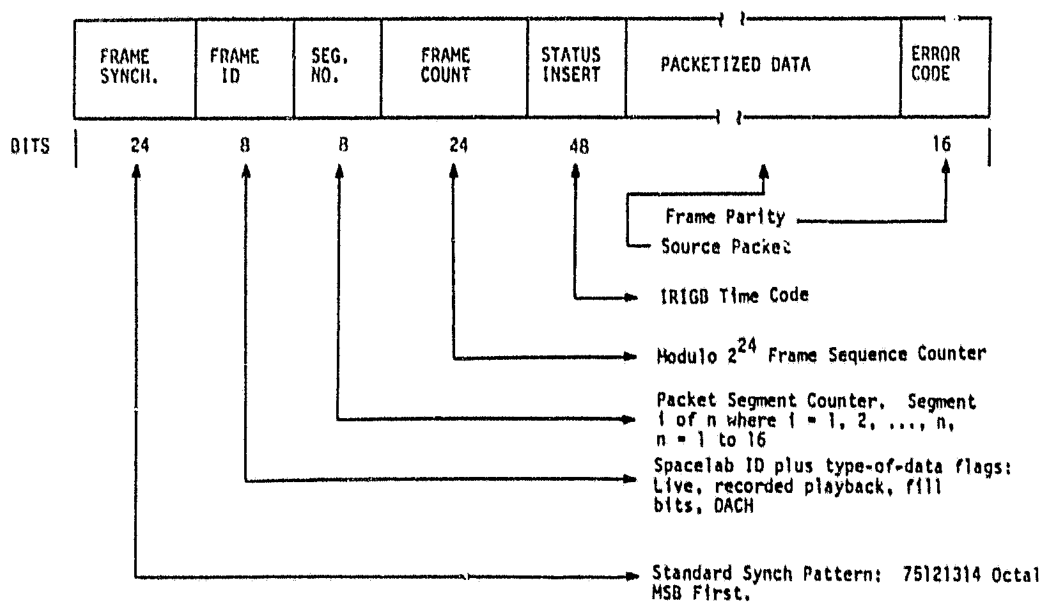


Figure 3-2. SPACELAB MINIMUM OVERHEAD TRANSPORT FRAME

to its respective (one of typically 20 pairs) INPUT packet image is accomplished by the ancillary data processor.

Packet parity is assigned only after all other bits in the packet have attained their OUTPUT values. The CRC code can be generated either by microprocessor software or by an offline bit serializer with a CRC chip. A more detailed trade study is necessary in order to determine the better method.

3.3.3 Tape Recorder Management

Two of the inputs to the HRPM are playback data from the Spacelab High Data Rate Recorder and the Orbiter Payload Recorder. The HRPM is required to interleave playback data with live data, presenting the composite data stream to the KUSP for downlink.

The HDRR records data whenever the space-to-ground link cannot be used. The HDRR is played back in the reverse direction when the downlink is available and is interleaved with live data. Typically the recorder plays back at a much higher bit rate than the live data. On the ground the composite data stream is separated into live and recorded data and the HDRR data is recorded on High Density Tape (HDT). The HDT is played back later offline at a slower rate in reverse, and when it is, the bit stream is in the same order as it came from the source experiments.

When the HDRR is played back on board, the reversed bit stream is loaded into new transport frames but not into new packets. An identifying flag is set in the header of each frame carrying playback data so that ground equipment can strip off the "new" transport frames before routing the data to the HDT. In this way the bit stream arriving at the HDT on the ground matches that leaving the HDRR on orbit.

3.3.4 Control

The subsystem computer IO (SCIO) is used for Initial Program Load (IPL) and for issuing commands to the HPRM. The commands are used to execute Built-In Test Equipment (BITE) sequences, request status or memory, select clock rates and command output routing.

3.3.5 Packaging

Three packaging options were considered for the HRPM (Table 3-3), the preferred approach being exact replacement of the HRM with a new box which is plug and pin compatible. The overriding advantage to this approach is that no modifications are required to any Spacelab hardware.

Table 3-3. HRPM PACKAGING OPTIONS

APPROACH	ADVANTAGES	DISADVANTAGES
1. EXACT REPLACEMENT OF HRM	o NO MODIFICATION TO ANY SPACELAB ARE	
2. INTERNAL MODIFICATION OF HRM	o SALVAGES MOST OF THE HRM CIRCUITRY	o PACKETIZER MAY NOT FIT WITHIN CONSTRAINTS
3. ADDITION OF A SECOND BOX OUTSIDE THE HRM	o SALVAGES MOST OF THE HRM	o NEW BOX MAY NOT FIT WITHIN IGLOO o IGLOO WIRING CONSTRAINTS MAY PROHIBIT LOCATING NEW BOX OUTSIDE IGLOO

With this approach the design envelope for the HRPM is identical to that of the HRM:

- o Dimensions (LWH): 15.4 X 19.6 X 7.6 in.
- o Limit Mass: 21.9 Kg
- o Electrical Power: 24 - 32 VDC @ 4.55 Amp
- o Heat Dissipation: 118.5W
- o Interface: Plug and Pin Compatible with HRM

Recent advancement in the state of the microelectronics art is such that the HRPM easily fits within the above constraints, even though it contains far more storage and logic than the HRM.

The other packaging options were considered because, from a functional standpoint, most of the logic in the HRM can also be used in the HRPM. The disadvantage in trying to salvage the HRM circuitry is that it will consume most of the available volume and thermal capacity, leaving little for the packetizer. If the packetizer is put in a new box outside the HRM and the existing HRM modified and retained, there may not be enough room in the igloo for the new box. (The CDMS is housed within a pressurized container called the "igloo" for pallet-only flights. The igloo is mounted in front of the forward-most pallet in the hard vacuum environment of the cargo bay.) The new box probably cannot be put outside the igloo because of pin limitations at the feed-through connectors. Consequently, total replacement of the HRM appears to be the only practical packaging approach.

3.4 OPERATIONAL CHARACTERISTICS

3.4.1 HRPM Flight Operation

The HRPM has the same operational features as the HRM:

(1) Outputing of live data to the 2, 4 and 50 Mb/s ports of the Orbiter Ku Band Signal Processor (KUSP).

(2) Outputing of "direct dump" data from either the Spacelab High Data Rate Recorder or the Orbiter Payload Recorder to any of the above ports.

(3) Outputing of live data to either of the above recorders.

(4) Interleaving of live data with data from either of the above recorders for downlinking.

(5) Outputing of either of the two DACH's to the 50 Mb/s port of the KUSP.

(6) Outputing of either of the two DACH's to the High Data Rate Recorder.

(7) Digitizing of 3 intercom voice channels (creating separate voice packets).

The HRPM can be programmed to deliver a synchronous transport frame stream at any rate shown in Table 3-4. The output rate must be sufficiently high to exceed the sum of the average input rates plus packet and transport frame overhead. The output bit rate remains constant regardless of fluctuations in packet traffic levels. The HRPM accomplishes this by insertion of "fill bits" in all unused transport frames. The output bit rate normally is changed only at predetermined times in the timeline. Currently, there is no provision in Spacelab to adaptively change bit rates to accomodate high data rate experiments when they encounter unpredictable targets of opportunity.

Three types of data may be carried by Spacelab-originated transport frames: live, pre-recorded playback and fill bits. A code within the "FRAME ID" field indicates which type of data is contained within the data field of each transport frame. The most common data type is live data downlinked directly from the High Rate Packet Multiplex on board Spacelab. The Spacelab data handling system has the capability to record digital data for playback downlinking at a later time. This

Table 3-4. PROGRAMMABLE OUTPUT RATES FROM THE HRPM

BITS/SEC	WORDS/SEC	FRAMES/SEC*
125K	7.8125K	40.7
250K	15.625K	81.38
500K	31.25K	162.76
1M	62.5K	325.52
2M	125K	651.04
4M	250K	1.302K
8M	500K	2.604K
16M	1M	5.208K
32M	2M	10.417K
48M	3M	15.625K

*Based on a frame length of 192 words

[illegible] is used primarily to preserve data acquired during the times when the Spacelab/Orbiter is out of radio contact with the TDRSS. The data stream going to the recorder is identical to a downlinked data stream. Time tags and sequence numbers are assigned at the time of queuing. On playback the reversed data stream enters "new" transport frames with time tags and frame counters assigned at downlink time. Table 3-5 shows the data rates available for live data when the recorder is being played back.

The Spacelab Packet Data System has the capability to transmit a continuous stream of transport frames whenever Orbiter is in radio contact with the TDRSS. If at any given time no source packets are ready for downlinking, the HRPM inserts a fixed "fill bit" pattern into the data field of each transport frame and sets the appropriate flag in the header. The fill bit pattern is TBD, but can be chosen to be a sequence which provides a known monitor pattern, thereby serving as a link quality check.

Table 3-5. DOWNLINK CAPABILITY AVAILABLE TO HIGH RATE EXPERIMENTS

	KUSP Rate		Rate Available To High Rate Experiments (TF/S)							
			Interleaved High Data Rate Recorder Playback Rate							
	Mb/s →	TF/s →	0 0	2 650	4 1300	8 2600	12 3900	16 5200	24 7800	32 10 400
KUSP Ch 2 or 3	1	325	275	X	X	X	X	X	X	X
	2	650	600	X	X	X	X	X	X	X
KUSP Channel 3 only	4	1300	1250	600	X	X	X	X	X	X
	8	2600	2550	1900	1250	X	X	X	X	X
	16	5200	5150	4500	3850	2250	1250	X	X	X
	32	10400	10350	9700	9050	7750	6450	5150	2550	X
	48	15625	15575	14875	14275	12975	11675	10375	7775	5175

Notes: 1. TF/S = Transport Frames/second
2. Overhead = 50 TF/S
3. 1TF = 192 Words = 3072 bits

The Spacelab CDMS provides two "direct access channels" which allow the user to bypass the HRM and feed data directly to the Orbiter Ku-Band Signal Processor. In the packetized data system these channels are used to accomodate sophisticated users who generate their own transport frames. Although Spacelab provides this service, it does not monitor the DACHs or warrant that the transport frame format, bit rate, and quality are compatible with packet standards. Obviously the sequence numbers of packets entering the system via a DACH will not be correlated with those issued to HRPM - originated packets.

3.4.2 Packet Mix

The packet mix downlinked by Spacelab in general is a function of both the flight configuration and the mission timeline. Two of the packet sources, the SCIO and ECIO, are synchronous fixed data rate inputs which operate at 1472 and 1280 words per second, respectively. For a transport frame of 192 words, this translates into 8 transport frames per second for the SCIO and 7 for the ECIO (excluding low rate experiment data). When all three intercom voice channels are being downlinked (a function of the mission timeline), transport frames are generated at the rate of 33 per second. Thus, the fixed synchronous load is 48 frames per second. The portion of the HRPM bit rate left over after accomodating the above is available for use by the high rate experiment channels, low rate experiments, (on the ECIO), and the High Data Rate Recorder (See Table 3-5). It can be seen from the table that, when there is no interleaved recorder playback, channel 2 of the KUSP can handle up to 600 transport frames per second of high rate experiment data. Interleaved playback of the recorder forces use of channel 3 of the KUSP, providing data rates of 600 to 14,875 frames per second to the high rate experiments.

3.4.3 Payload/Mission Planning Function

The payload/mission planning function for the packet data handling system involves some additional aspects beyond the current system. The mission manager has the responsibility of assigning "SOURCE ID" numbers to each experiment data source from the list of numbers available to the payload. More importantly the mission manager must allocate the available packet memory to the experiments by selecting the length of packet for each experiment. For example, with a 16-bit, 256K packet memory, approximately 50K is preallocated for Spacelab overhead. The remainder can be divided among the experiments in whatever way the

mission manager sees fit. A general rule of thumb is that the memory allocation must be twice the length of the packet for each data source. (It is more for short packets.) The total storage capacity of the HRPM is independent of the length of transport frame selected. When longer transport frames are used, fewer can be stored in packet memory.

3.5 DEVELOPMENT SCHEDULE

It is anticipated that the High Rate Packet Multiplexer development would be approximately a 33-month program. It is assumed that five units would be required: a qualification unit, three flight units and a spare. Also assumed is that two sets of special test equipment (STE) will be required to support qualification tests and factory tests. The following sections give a more detailed explanation of the schedule and the required manloading. The estimated cost is provided in Section 5.

The HRPM development schedule (Figure 3-10) shows the major milestones, phasing and approximate manloading on each task. A work breakdown structure is shown in Figure 3-11. The first major task is SYSTEM ENGINERING/TECHNICAL MANAGEMENT. This is a three-man level effort for the first year with two men assigned to the HRPM and one to STE. These individuals would develop conceptual designs, write specifications, and conduct the NASA reviews. At critical design review (CDR) conclusion, this effort would drop to 2 men, one HRPM and one STE. These two individuals would be responsible for overall technical management of the program through installation and checkout.

The next major task is hardware design. This is broken into three main areas: electrical design, mechanical design, and microprocessor (application) system design. This effort begins immediately after the preliminary requirements review (PRR). Betwen PRR and CDR one additional electrical and two additional mechanical designers are added to perform the detailed design required at CDR. Two individuals will concurrently develop the microprocessor system design. One will be a hardware designer and the other a software engineer. After CDR an additional software designer/programmer is added until first delivery.

The HRPM fabrication and checkout task begins immediately after CDR. This effort does not require an exotic technological specialist,

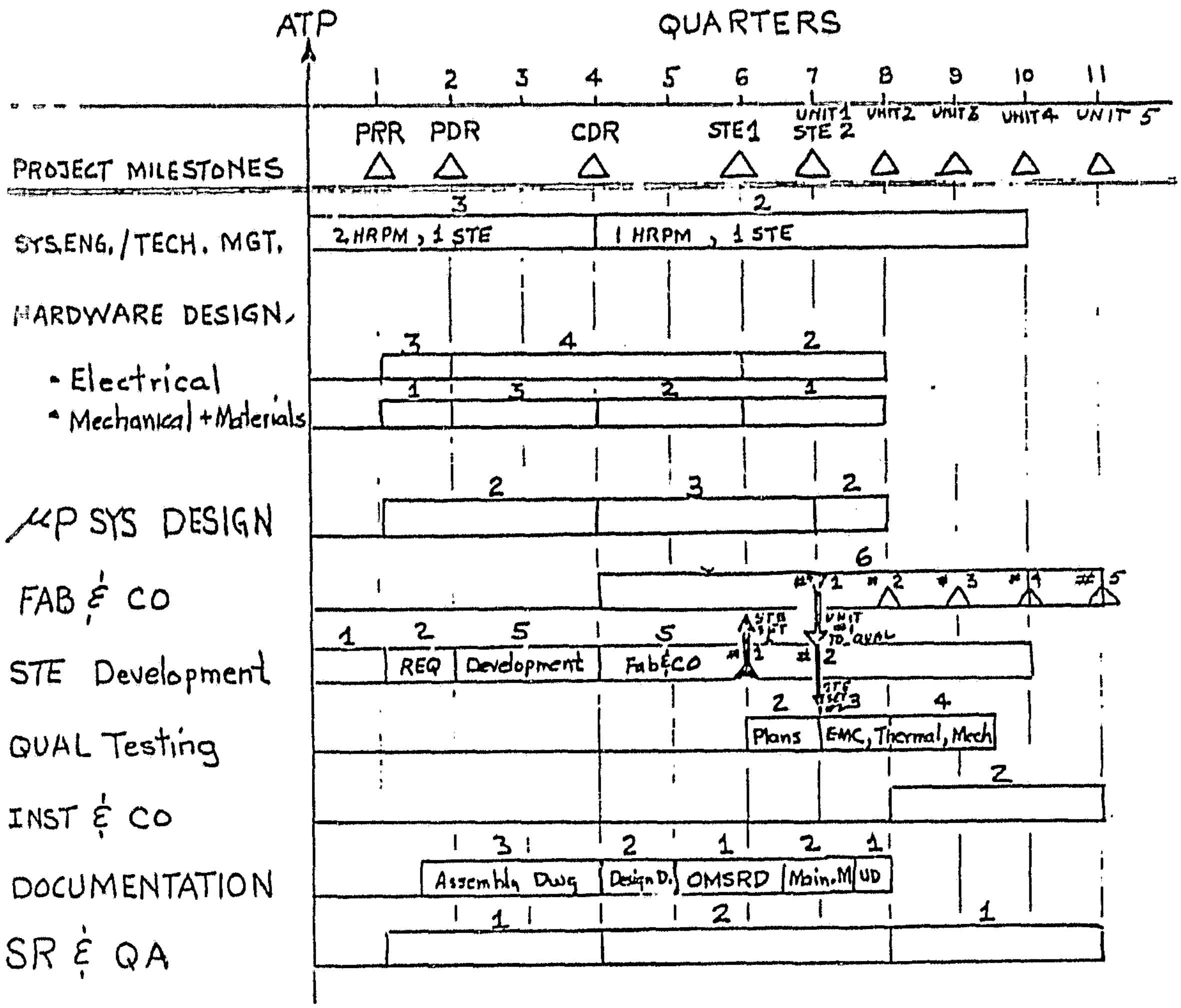


Figure 3-10. HRPM DEVELOPMENT SCHEDULE

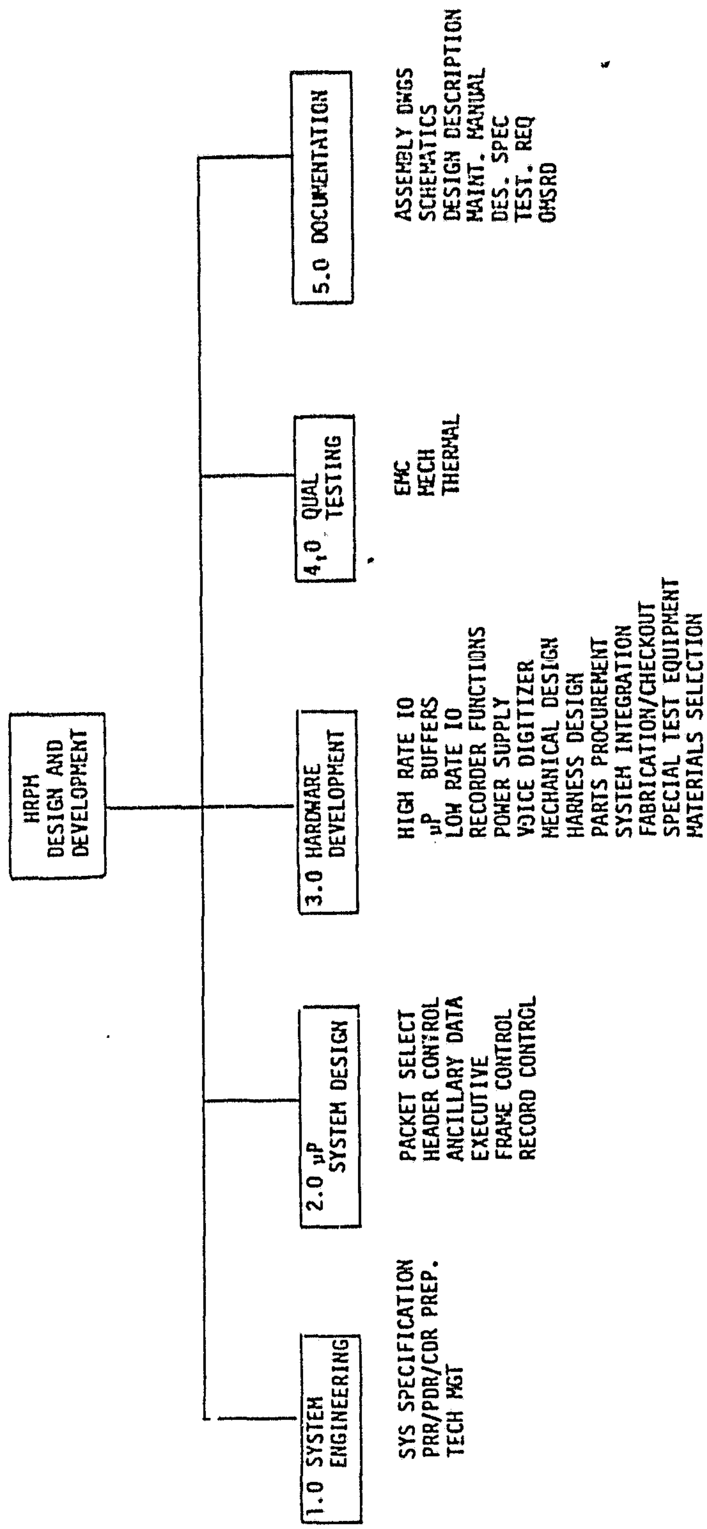


Figure 3-11. WORK BREAKDOWN STRUCTURE

and the packaging is similar to the existing HRM: single layer PC type cards and a back plane. This is a six-man level of effort through delivery of the fourth unit.

The next major task is the special test equipment development. It is assumed that there does not exist any test equipment which could be utilized to support factory test and environmental testing. Special test equipment therefore will be required, but a large part may be commercially available equipment supplemented with tailored interface designs. This effort begins at program start because the STE will be required to support factory checkout of unit #1 at approximately the sixth quarter. One man initially develops the required specifications and supports the PRR. This increases to two men (one mechanical and one electrical) to support the preliminary design review (PDR). The level jumps to five to perform the detailed design and fabrication. STE set #1 would be delivered to support factory test, and set #2 would support qualification tests.

The qualification testing is assumed to require three to four quarters and is assumed to be active testing. The initial effort required is to develop test plans and procedures, and is at a two-man level for one quarter. The level then increases to three and four to perform the detailed electromagnetic compatibility (EMC), thermal and mechanical testing. Actual testing is estimated to require two or three quarters.

The documentation task begins at PDR and requires three men. This effort will be devoted largely to development of assembly drawings, electrical schematics and wiring lists. The data output from this initial effort will largely constitute the CDR data package. This effort reduces somewhat for the remainder of the program, and the outputs would consist of the operational and maintenance requirements specification document (OMRSD), design description, operation and maintenance manual, and updates to drawings as required.

The final efforts shown near the bottom of the schedule are configuration management and SR&QA functions. The configuration management effort is required to incorporate all drawings and documents into the Spacelab configuration management system and to maintain configuration control of documentation and hardware. The SR&QA functions shown on the schedule begin at PRR and continue through delivery of the final unit. This effort is required to perform supporting analyses required for CDR and to monitor development of both flight hardware and test equipment.

3.6 PRELAUNCH GROUND PROCESSING

The most significant change which must be made to the prelaunch ground processing equipment in order to accomodate the full packet data system is the replacement of the HRDM with a "Packet Demultiplexer" (PDM). The Packet Demultiplexer is a new development which accepts a serial packetized data stream of up to 50 Mb/s as produced by the HRPM. The PDM performs bit synchronization, transport frame sync pattern recognition and packet switching to multiple output buffers. These buffers store packets from each source ID and clock out the packets at the proper bit rates. Separate output ports are provided for HDRR output, ECIO and SCIO utility packets, voice packets and analog, low rate experiment data and high rate experiment data.

Figure 3-12 shows the data flow for Level IV and Level III/II ground processing at KSC. The shaded blocks are the elements that would be impacted if Spacelab were converted to the full packet data configuration. In both levels the HRDM is replaced with a PDM. The present PCM Decommutators are compatible with packet protocol and can continue to be used. In Level IV the Computer Interfacing Device (CID) is compatible with packets, but some software modifications are necessary in both of the Interdata 832 computers (PCU and ECEP). The HRM I/O Test System (HITS) computer software in Level III/II will require similar changes.

The cost estimate for ground processing given in Section 5 is only for development of the PDM. More study is needed to estimate the other costs.

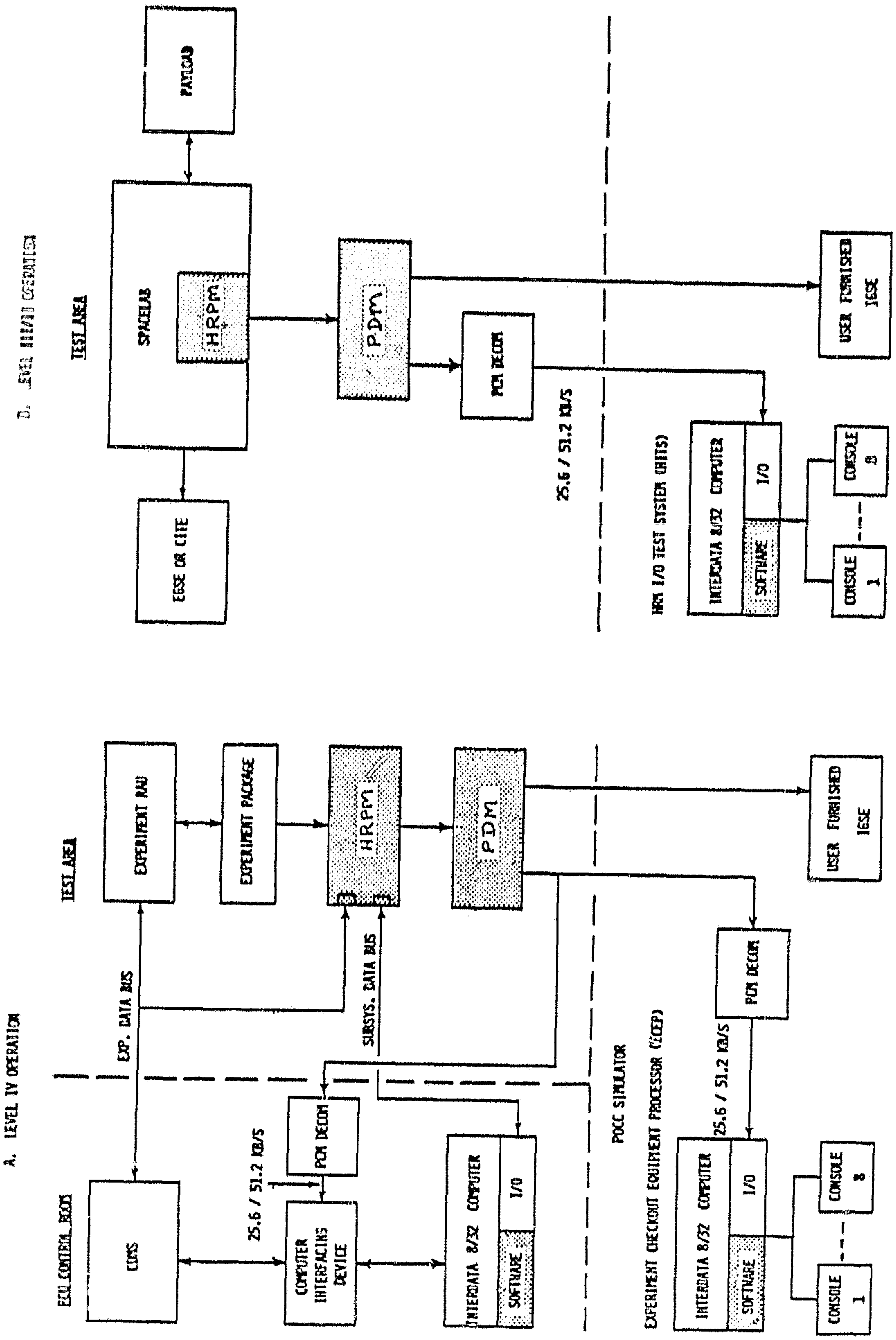


Figure 3-12. PRELAUNCH GROUND PROCESSING, FULL SYSTEM

SECTION 4
HYBRID SYSTEM

4.1 OVERVIEW

The hybrid packet data system concept is based on the premise that all high data rate experiments (those designed to interface with one of the 16 high rate input channels of the HRM) will have their own dedicated experiment processors (DEP's). These DEP's either already are programmed or can be reprogrammed to produce packet formats. In this scenario the HRM-HRDM downlink path can be maintained essentially intact, since it is transparent to the packets. Packets entering the HRM input channels on orbit will emerge from the corresponding HRDM channels on the ground unaltered.

Figure 4-1 shows a functional block diagram of the end-to-end hybrid system. The experimenter can route data to the Experiment Computer for on-board display and downlinking. He can also route data directly to the HRM for downlinking via the Orbiter Ku Band Signal Processor to the earth stations at JSC and GSFC. At JSC the user can attach his own Instrument Ground Support Equipment (IGSE) to his raw data stream via ports within the POCC. He can also display some of his data via POCC systems, provided he meets certain format restrictions.

At GSFC Instrumentation Data Tapes (IDT's) can be created for the User. He can also have his data recorded on Computer Compatible Tapes (CCT's) with HDRR overlap removed or have it entered in a packet distribution network, provided his data is in packet format.

Low data rate users (those who enter their data into the system via RAU's) can obtain some of the same services at JSC and at GSFC. The ECIO data stream is decommutated in real time at the POCC, and experiment parameters can be displayed. There is also provision for four direct ports to IGSE. At GSFC low rate data can be decommutated from the ECIO.

Two key issues arise in attempting to implement the hybrid concept:

(1) What format restrictions should be placed on the high rate channel user?

(2) What can be done to facilitate the handling of ECIO data?

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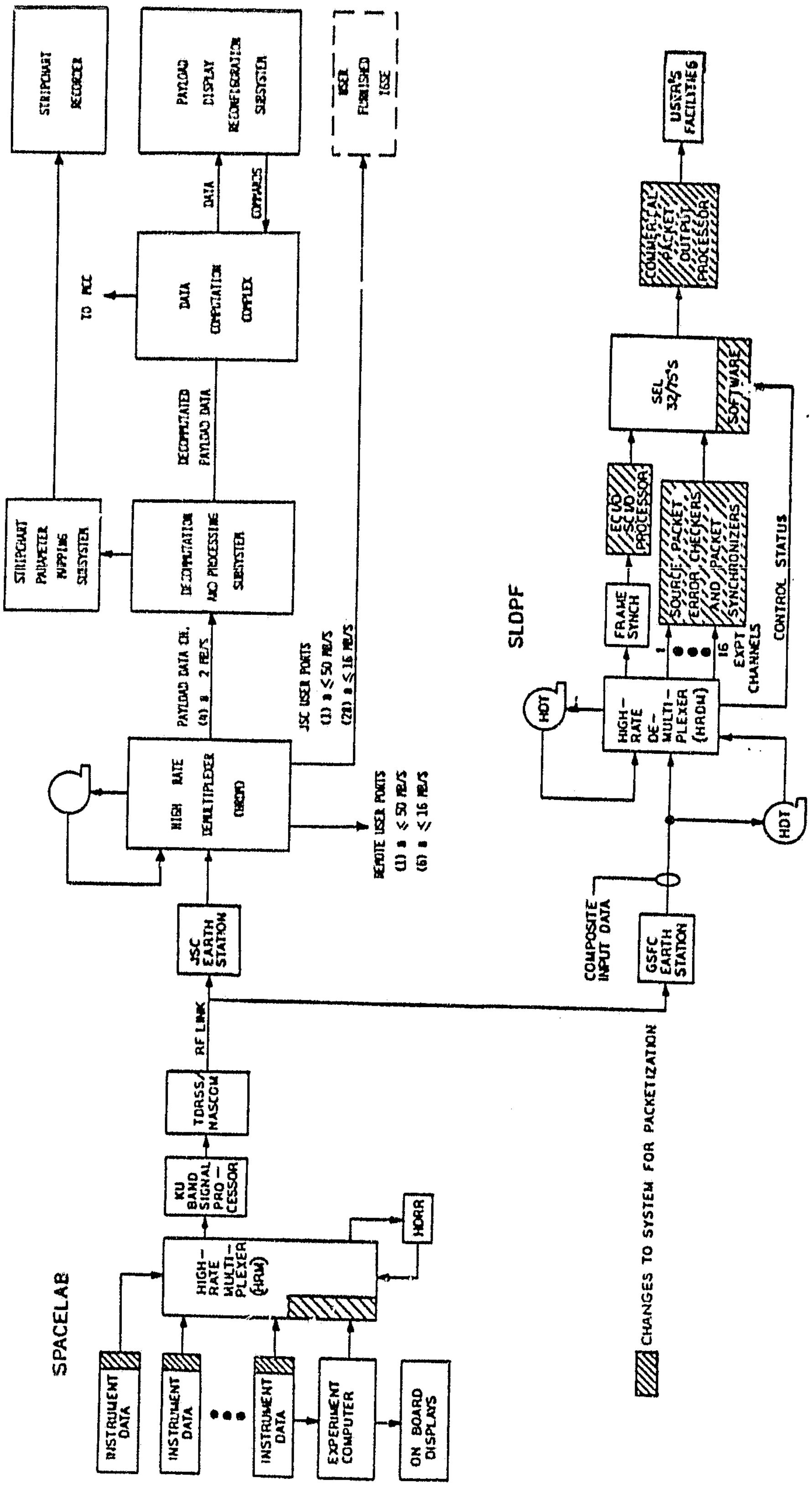


Figure 4-1. FUNCTIONAL BLOCK DIAGRAM OF THE END-TO-END HYBRID SYSTEM

These two questions formed the basis for phase II of the study to define the hybrid system. The approach taken was to answer the high rate question first and then apply the same format requirements to the decommutated ECIO. Subsection 4.2 summarizes the results of the high rate format study and the following paragraphs along with subsections 4.3 and 4.4 cover the ECIO decommutation problem.

Four options were identified for solving the ECIO problem:

(1) A dedicated on-board packetizer inserted between the Experiment Computer and the HRM

(2) A redesign of the Experiment Computer and its operating system to perform the necessary decommutation and packetization

(3) An ECIO/SCIO decommutator and packetizer located on the ground (possible derivative of the HITS/ECEP system at KSC)

(4) Addition of a low rate pre-mux to the HRM for low rate experiment data, along with an operational constraint excluding any low rate experiment data from the ECIO which requires SLDPF processing.

Of these, Options 1 and 2 are discussed in subsections 4.3 and 4.4 respectively. Option 3 is outside the scope of this study, but is recommended as a candidate for further study. (See section 5). Option 4 does not appear as attractive as the others unless additional justification for developing a low-rate pre-mux is forthcoming.

4.2 HIGH RATE DATA FORMATS

In the context of the hybrid system the format restrictions imposed upon the high data rate user are a function of the ground services desired; i.e., the more ground services desired, the more restrictive the format. Table 4-1 illustrates this. If no ground services are desired, or if the experimenter only wants his raw data stream routed to his own IGSE, then the only restriction is that his instrument not exceed the maximum bit rate expected by the HRM by more than one percent. An excessive bit rate causes the HRDM to overflow, losing some of his data.

If the experimenter desires recording of his raw data via GFE recorders at any ground facility, he must, in addition to the above, guarantee a minimum bit rate within one percent of the nominal in order to be compatible with IDT recorders. This restriction applies to the KSC Level IV and prelaunch operations, JSC POCC and GSFC SLDPF. As a result of this restriction an experiment producing packets must generate an idle pattern when no packets are ready for downlinking. This restriction negates one of the advantages enjoyed by the full packet data system; viz, downlink bandwidth is allocated to a data source only when it has valid data to downlink.

The next level of restrictions applies to the situation where the user desires post-mission data staging services from the SLDPF. Examples of such services are the creation of computer compatible tapes with the HDRR overlaps removed and the delivery of source packets via commercial networks. It is projected that in the packet era the SLDPF will have been converted to the hybrid configuration of Figure 4-1. In this configuration the SLDPF will require an adaptation of the Guideline 3.3 format for any processing of digital data beyond the creation of IDT's - hence the format restriction shown in the table.

Table 4-1. FORMAT RESTRICTIONS VS. GROUND SERVICES

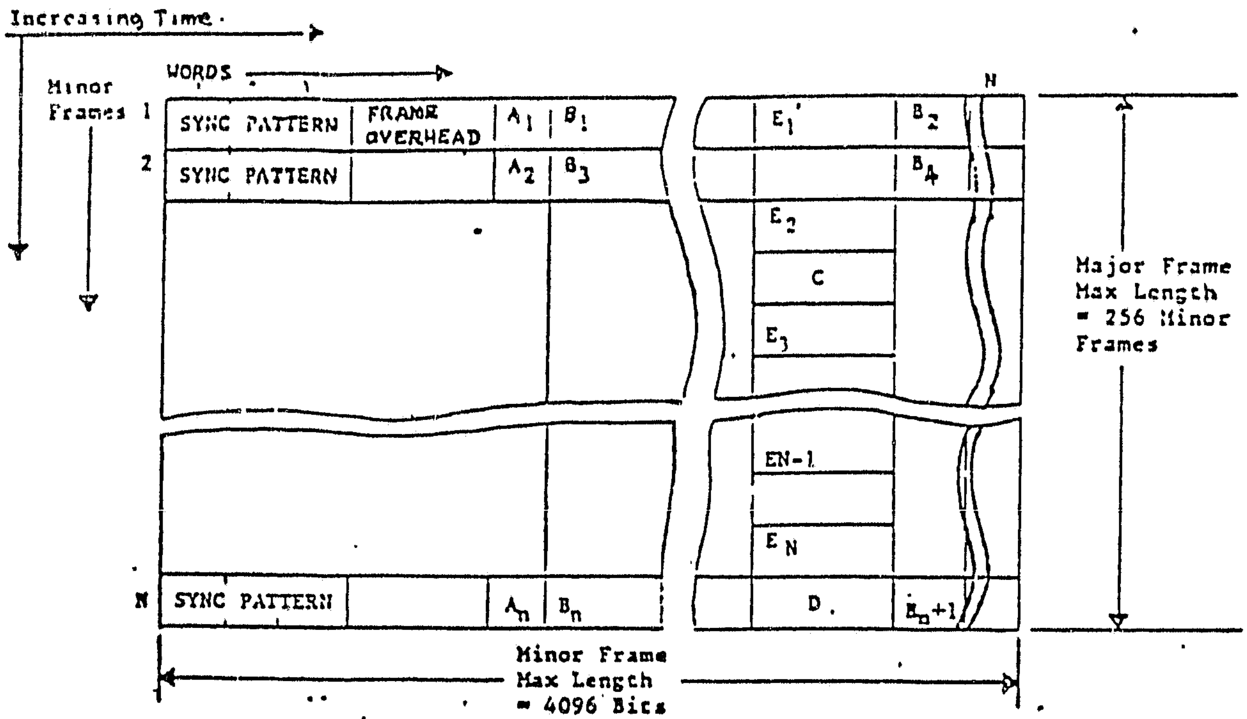
LEVEL OF DESIRED GROUND SERVICES	FORMAT RESTRICTIONS			
	MAX BIT RATE (+1%)	MIN BIT RATE (-1%)	PACKET FORMAT	MINOR FRAME/ MAJOR FRAME FORMAT
(1) ROUTING FROM HRDM TO IGSE	✓			
(2) IDT's FROM GFE RECORDERS	✓	✓		
(3) POST MISSION PROCESSING & STORAGE	✓		✓	
(4) DISPLAY ON POCC TERMINALS	✓	✓		✓

Finally, if the user desires display of some of his data on POCC terminals and/or recording on POCC stripchart recorders, he will have to meet the POCC minor frame/major frame requirements as well as the bit rate tolerances. Perhaps the most profound result of this restriction is that a single channel of the HRM-HRDM may have only one length of packet or one fixed packet string (major frame in PCM terminology) for any HRM format configuration.

It can be seen from Table 4-1 that a user desiring both POCC display and SLDPF processing must meet both the minor frame/major frame and the packet format requirements. Figure 4-2 shows the minor frame/major frame format required for POCC display, as taken from the POCC Format Standard (Appendix B). The minor frame can range in length from 56 to 4096 bits, and the major frame can range from 4 to 256 minor frames (224 to 1,048,576 bits). This means that a high data rate source can generate repetitively a fixed string of packets up to 63,488 16-bit words in length, using the maximum length minor frame of 4096 bits (256 16-bit words) with the 8-word overhead in Figure 3-2. Every minor frame must have a 24-bit sync pattern and an 8-bit frame count.

Figure 4-3 shows a typical example of the recommended format for the high data rate users of the hybrid system. It is an adaptation of the Guideline 3.3 format of Figure 2-4 which meets the POCC requirements of Figure 4-2. The illustration in Figure 4-3 is a serial bit stream which might be generated by a typical experiment and presented to one of the high data rate input channels of the HRM for downlinking. In this example the experiment DEP has merged packets of different lengths from three different sources (A, B and C) and has embedded them within transport frames. This three-packet string is repeated in the same order throughout the mission whenever the experiment is sending data. The "FRAME COUNT" and "FRAME ID" fields in the transport frame header are interchanged from Guideline 3.3 to comply with POCC usage. The packet format is in complete compliance with Guideline 3.3.

The bit stream in Figure 4-3 will emerge unchanged from one of the HRDM output channels at the SLDPF. It is fed into a "Packet Synchronizer" where the transport frames are stripped off. The same bit stream emerging from the HRDM at the POCC is interpreted as a minor frame/major frame sequence. The minor frame corresponds to the transport frame and in this example the major frame



A_N — Example of normal commutation — one sample in each minor frame.

B_X — Example of a super com — the time interval between samples B_1 and B_2, B_2 and B_3, B_3, and B_4, B_n and B_n+1 is identical.

C & D — Examples of a subcom — C and D have less than one sample per minor frame.

E_X — Example of super commutation a subcom — the time interval between samples E_1 and E_2 and E_2 and E_3 - . . . EN-1 and E_N are identical.

Figure 4-2. POCC FORMAT REQUIREMENTS

FRAME SYNCH.	FRAME COUNT	FRAME I.D.	SEGMENT NO.	STATUS INSERT	SOURCE I.D.	MISSION I.D.	SOURCE SEQUENCE COUNT	PACKET LENGTH	SPARE	SECONDARY HEADER I.D.	SOURCE I.D. PARITY	SECONDARY HEADER	SOURCE DATA	ERROR CODE
SYNCH	000	L	1/3	TIME	A	SL6	517	LA		HA	A'	AD		EC
SYNCH	001	L	2/3	TIME	SD									EC
SYNCH	002	L	3/3	TIME	SD								PP FILL	EC
SYNCH	003	L	1/1	TIME	B	SL6	123	LB		HB	B'	AD	PP	EC
SYNCH	004	L	1/1	TIME	C	SL6	731	LC		HC	C'	AD	PP FILL	EC
SYNCH	005	L	1/3	TIME	A	SL6	517	LA		HA	A'	AD		EC
SYNCH	006	L	2/3	TIME	SD									EC
SYNCH	007	L	3/3	TIME	SD								PP FILL	EC
SYNCH	008	L	1/1	TIME	B	SL6	123	LB		HB	B'	AD	PP	EC
SYNCH	009	L	1/1	TIME	C	SL6	731	LC		HC	C'	AD	PP FILL	EC
BITS 24	8	8	8	48	UP TO 3984									16

NOTES: 1. THE SOURCE PACKET FROM SOURCE ID "A" IS HEAVILY OUTLINED.
2. SECONDARY HEADERS NEED NOT BE THE SAME LENGTH.

Figure 4-3. EXAMPLE OF RECOMMENDED HYBRID FORMAT

corresponds to five minor frames. (The major frame can contain up to 256 minor frames.) Any variables within the packets or the transport frames can be designated for POCC display or stripcharting. The time code in the "STATUS INSERT" field of the transport frame is used to drive the time scales of the displays and stripchart recorders at the POCC.

It can be seen from the foregoing example that it is feasible to satisfy the format requirements of both the POCC and Guideline 3.3 simultaneously. The only modification necessary at the POCC is a software change to drive the displays and stripchart recorders from the frame "STATUS INSERT" field rather than the present time code fields.

4.3 DEDICATED LOW RATE PACKETIZER

The first option to decommutating the low rate experiment data is the "dedicated low rate packetizer." The low rate data packetizer is a computer driven, dual input/output, special purpose format generator. The hardware design is driven by the conflicting concepts of real time display (at the POCC) and packet data delivery (at GSFC). This subsection discusses the various system concepts applicable to Spacelab data management and presents a microprocessor based implementation for a general purpose packet formatter.

4.3.1 Format Concepts

Data from Spacelab experiments classified as producing low rate data are acquired via RAU under EC/ECOS control. Each acquired data message (less than 32 words) is assigned downlink positions within the ECIO format based on the triplet execution rate (sample frequency).

This is time division multiplexing at the message/sub-message level. All data acquired by each triplet execution must be downlinked before the next execution of that triplet. Utilizing this concept the 3200-word ECIO format does not exist as an entity within EC memory. An ECIO format occurs serially within the 51.2 Kb/s downlink data stream one time per second, as 20 minor frames, each consisting of 160 words. All downlink formats must retain the repetitive minor frame, major frame structure necessary for sync detection by ground systems.

The SCIO format is similar to the ECIO; however, the subsystem data rate is only 25.6 Kb/s and a minor frame is 80 words in length. The formatting task becomes one of transposing a time division multiplexed (TDM) data stream at the message/sub-message level to a TDM data stream at the multiple message level.

A typical ECIO packet compatible format could maintain the 160 words per minor frame of the current format; however, 240 minor frames occurring over a 12 second interval would be required to complete a typical format (major frame). The minor frame length must be less than 512 words (16 bits each) with the total format not exceeding 256 minor frames in order to meet POCC requirements (Appendix C). A packet compatible major frame as shown in Figure 4-4 would contain in the data field 8 minor frames dedicated as an EC utility packet and 232 minor frames available for low rate experiment packets. Each low rate experiment ID must be assigned at least one minor frame per major frame (maximum packet length 156 words per minor frame) and may be assigned additional sequential minor frames as required to encapsulate a packet. Assuming 20 low rate experiment ID's, the average packet length could approach 1800 words of 16 bits each with a maximum possible packet length approaching 36,000 words. The actual format would be of composite structure to maintain features of the current format (POCC compatible) while incorporating a packet (GSFC) precurser.

Consider the composite format shown in Figure 4-5. The format retains the 24 bit sync pattern, frame count and auxiliary data field of the current ECIO. The functional capabilities of these fields are very similar to the functions associated with the transport frame of Guideline 3.3. The remaining unassigned sequential words of each minor frame contain sequentially a packet or for long packets a segment of a packet. The packet data fields are not restricted to a particular packet or non-packet format; however, all experiment user ID sequences begin as a sync in the fifth minor frame word. The composite format consisting of 240 minor frames of 160 words each can be decommutated by standard telemetry hardware to yield a serial packet data stream with sync packet delimiters.

4.3.2 Downlink Options

A data flow diagram for the composite format and for two alternative concepts is shown in Figure 4-6. The EXTRA CHANNEL and the COMBINED IO seek to solve conflicting format requirements by keeping the current format while adding a packet format.

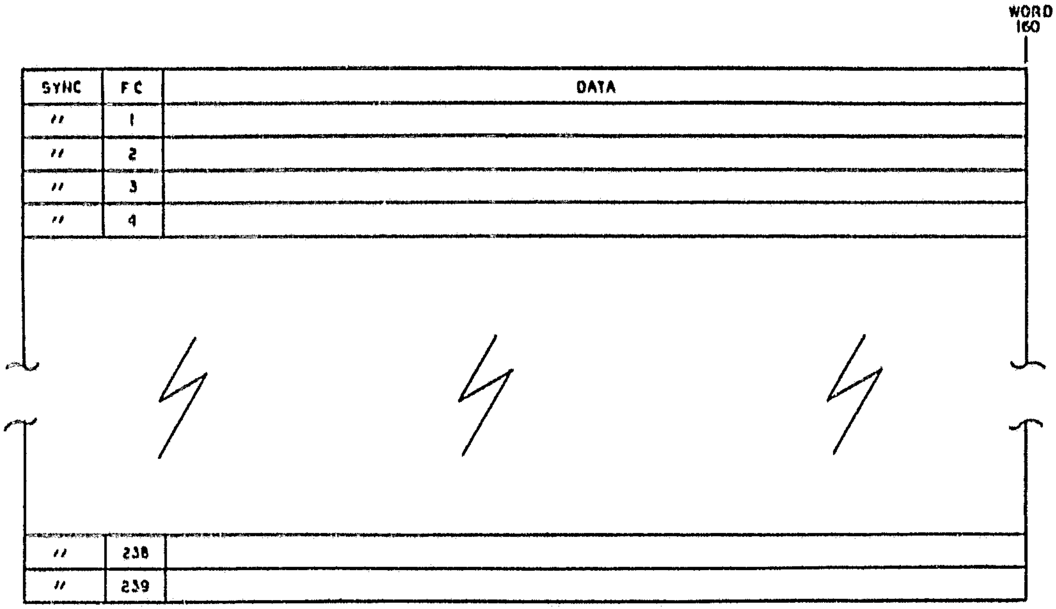


Figure 4-4. PACKET-COMPATIBLE MAJOR FRAME

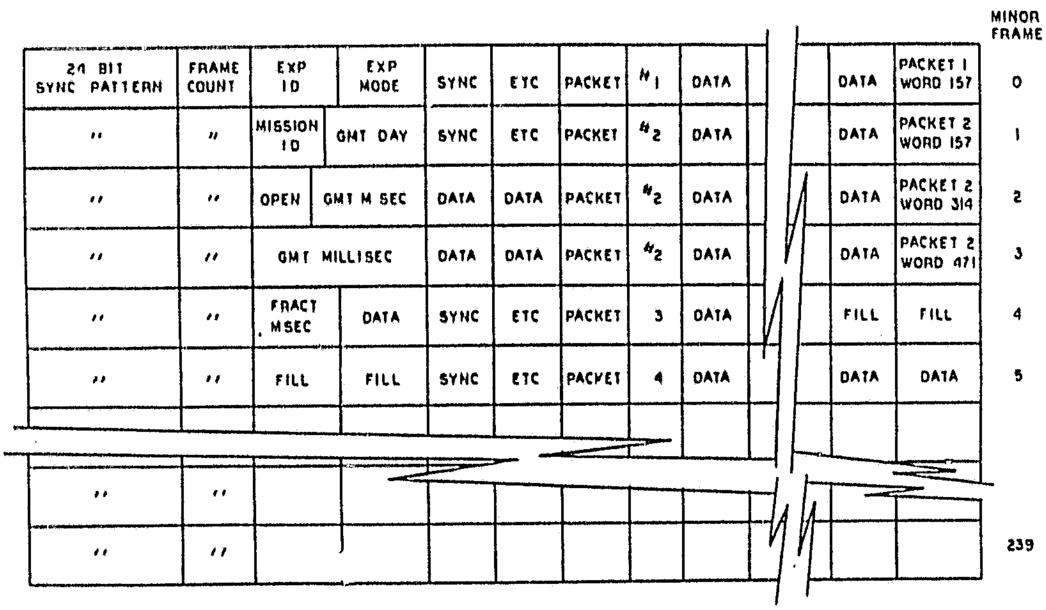


Figure 4-5. COMPOSITE FORMAT

Utilization of an HRM high rate channel to downlink unpacketized format for POCC use while simultaneously transmitting the packetized ECIO and SCIO data has been suggested. The concept suffers from requiring increased downlink bandwidth to transmit the extra copy. All multiple copy concepts increase the already severe constraints on the experiment timeline during periods of analog/video activity.

4.3.3 Hardware Description

The low rate packetizer utilizes microprocessor design concepts to assemble ECIO and SCIO serial data streams into a packet data format and to control the downlink sequencing of completed packets. (See Figure 4-7.) The input channels labeled ECIO and SCIO are CDMS computer interface links. The ECIO contains downlink data only; however, the SCIO issues commands to and receives responses from the HRM in addition to its downlink transfers. The packet processor is designed to be transparent to HRM commands and responses.

Experiment data arriving at an input channel will be stored sequentially in the packet memory image data field assigned to that experiment ID. Sync detector logic will allow experimenters to initialize their respective ID packet buffer load addresses if they so desire. Other input data will be routed to either the EC utility packet image or the SC utility packet image. Concurrently any variable from either input channel designated as ancillary data will also be written into the ancillary data buffer.

The ancillary data required for each packet is routed to each experiment ID and then each completed packet is sequenced to its respective output port in a fixed, premission defined progression. A completed progression has sequenced a composite format (major frame) to the HRM's ECIO port and has also sequenced a SCIO utility packet to the HRM's SCIO port.

The packet processor software system will consist of a mission independent resident program and of mission dependent software driven tables. Current mission operations plans will not require changing driver tables during a mission.

4.3.4 Performance Considerations

The real time data display mission of the POCC is degraded by the data buffering so fundamental to packet data systems. The selection of packet lengths

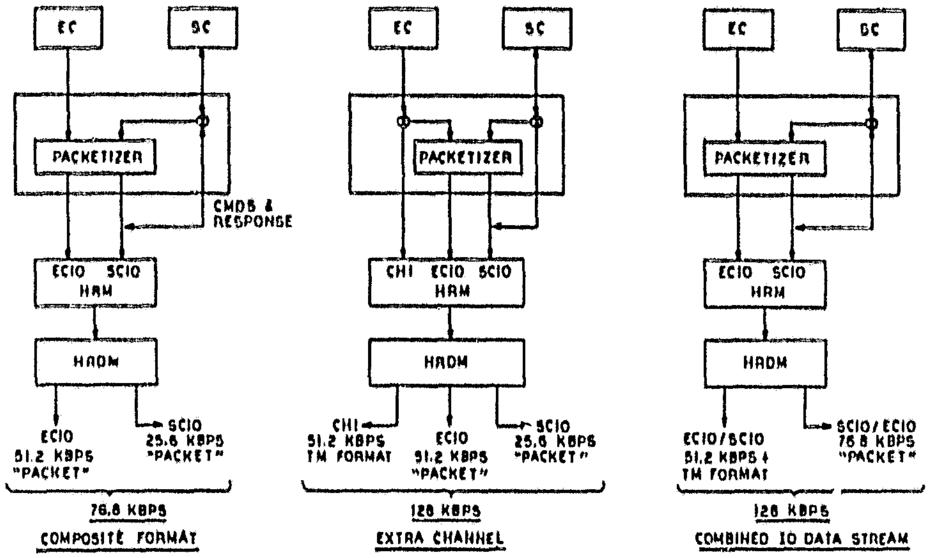


Figure 4-6. DOWNLINK OPTIONS

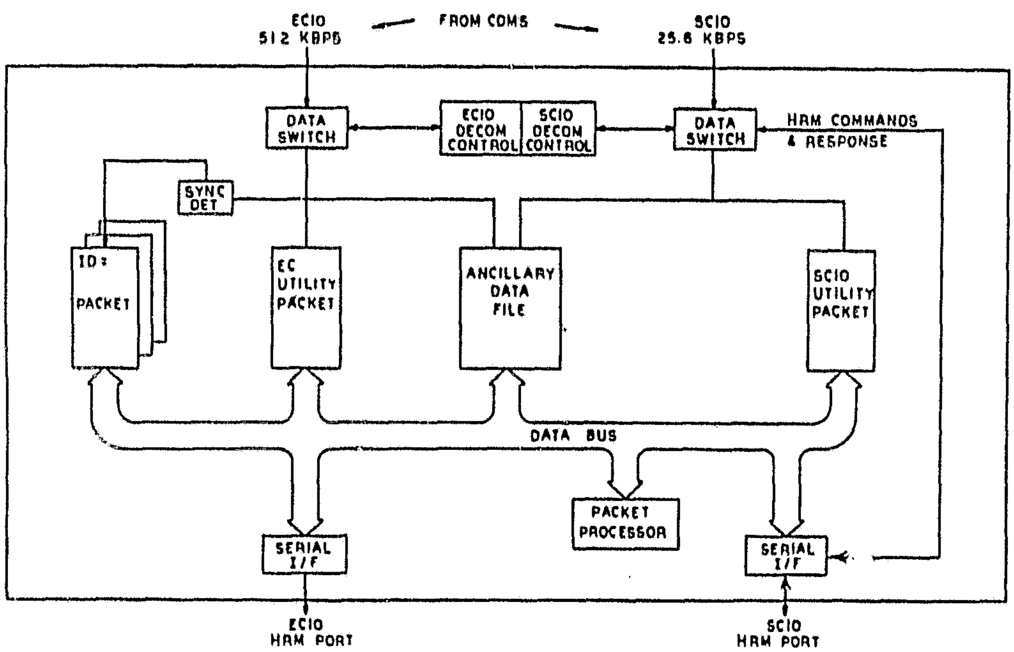


Figure 4.7. LOW RATE PACKET DATA FLOW

and the number of low rate experiment ID's being supported will determine the additional data display delay; however, a nominal 9-11 seconds should be anticipated.

The data processing/routing mission of GSFC is inherently a packet concept. The performance benefit GSFC will derive is limited primarily by the availability of the ancillary data during the packetizing process. In the Spacelab flight packetizer design only data within the EC/SC environment may be selected as ancillary data. Guidance and IPS state vectors are routinely included in the available data.

Placing multiple copies of ancillary data in the downlink reduces, by an equal amount, the downlink bandwidth available for experiment data. If each of the 20 ID's requested GN&C data one time per second, the maximum composite experiment data rate would be reduced by approximately 17 Kb/s.

The ECIO & SCIO data inputs to the packetizer are currently available at the HRDM output. The concept presented for onboard packetizing could be adapted to the GSFC HRDM output to obtain additional benefits:

1) Packetizer would not have to be flight qualified
2) No flight weight penalty
3) No downlink bandpass penalty for ancillary data copies
4) No verification of flight software.

4.4 LOW RATE PACKETIZATION VIA EC/ECOS REDESIGN

The second option of decommutating low rate experiment data is by means of modifying the Experiment Computer and its software.

Packetizing low rate data within th Experiment Computer will require ECOS to perform additional buffer, format and ancillary data management functions. Data from each experiment ID would be buffered to packet length and output in packet format with ancillary data encapsulated. The implementation would maintain the current General Measurement List (GML) data acquisition concept and ECOS onboard services; however the following areas would have major impact:

- o GML dependent output processing by ECOS
- o EC Memory
- o CPU Utilization
- o Support Software.

4.4.1 GML Dependent Output Processing

Data routing within the CDMS is GML derived. A GML-triggered acquisition triplet to an experiment ID results in a data message of up to 32 words being stored in a buffer specifically dedicated to that acquisition triplet. The next execution of that acquisition triplet writes into the same buffer locations; therefore output triplets write the data into the output format between acquisition triplet sequences. To generate a packet data ECIO format this input-to-output pipeline must be interrupted by extensive packet length data buffers for each experiment ID. Approximately 50% of ECOS must be modified in order to provide output processing compatible with a specified packet format.

4.4.2 EC Memory

Support for twenty packet ID's would require approximately 4K memory words for data buffering. Additional ECOS software routines to perform buffer, format and ancillary data management would require between 3K and 4K for instruction storage. The EC configuration is already memory critical; therefore packet data cannot be implemented without expanding the available memory. Expansion of the memory requires replacement of the present memory cards with the more compact 13-mil core type, which must be flight qualified. In addition the addressing scheme of the IO Unit is limited to 64K, necessitating redesign for expanded memory.

An additional concern is the impact that expanding the experiment computer memory would have on CDMS computer redundancy management. As a minimum the CDMS backup computer would require the same expansion.

4.4.3 CPU Utilization

Execution of the additional ECOS routines required to support packetization within EC/ECOS is estimated at 25% of CPU capability. The current ECOS CPU allocation (34%) and ECAS CPU allocation (66%) cannot be reduced without impacting Spacelab support services.

4.4.4 Support Software

Flight software is structured to be driven by Support Software derived tables. Modification of the GML dependent output triplet execution sequencing within ECOS will result in 45% modification of the CDMS Analysis Support Software

(CASS) table generation routines. A CASS expansion estimated near 25% is required to generate new packet dependent ECOS driven tables. Modification to various software development facilities will increase the impact to support software to near 75%.

4.4.5 Summary

Low rate packetization by EC/ECOS modification is not technically feasible. The reason is that the present computer is fully utilized in terms of both speed and memory. The entire EC would have to be replaced with more advanced hardware. This in turn would require rewrite of a large amount of flight and ground software

4.5 PRELAUNCH GROUND PROCESSING

The Hybrid implementation will require modification of all KSC GSE which checks, displays or simulates a Subsystem (SCIO) or Experiment (ECIO) computer downlink format. This type activity is the primary function of the shaded ground support equipment computers shown in Figure 4-8. The 20 minor frame per format applications software residing in the three computers (shown shaded) must be changed to process the 240 minor frames per format used in the Hybrid (composite) implementation. No hardware impacts have been identified.

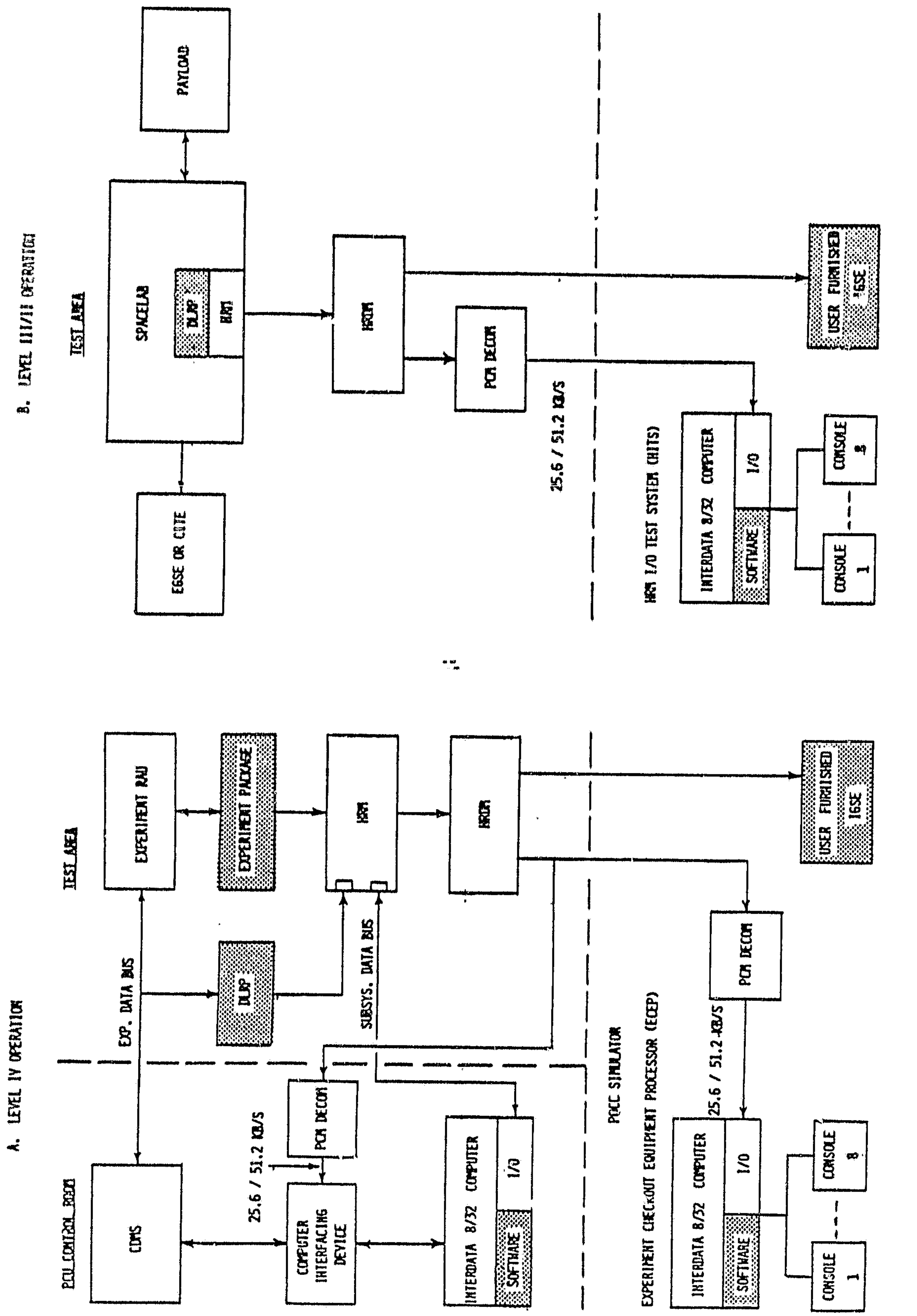


Figure 4-8. PRELAUNCH GROUND PROCESSING, HYBRID SYSTEM

SECTION 5
CONCLUSIONS

5.1 FLIGHT SYSTEM IMPLEMENTATION

Three major conclusions can be drawn from the flight system study:

1. It is technically feasible to fully packetize all measurement data on board Spacelab. However, implementation requires replacement of the High Rate Multiplexer with a "High Rate Packet Multiplexer" (Full System).

2. It is also feasible to packetize only the low rate data on board by the addition of a "Dedicated Low Rate Packetizer" (Hybrid System).

3. There is a significant savings in flight system cost if the low rate packetizer approach is selected (with the high rate data packetized by the experiments).

5.2 ALTERNATE IMPLEMENTATION

It appears feasible to mechanize the Low Rate Packetizer in the ground data handling system (Minimum Impact System).

There is no cost to the flight system at all if the dedicated low rate packetizer can be implemented in the operational ground based data handling system rather than on board. Such an implementation is technically feasible because the HRM/HRDM downlink is designed to be transparent. Ground implementation avoids the cost of flight qualification testing, and requires only one operational ground unit (at GSFC) as opposed to three flight units. A further advantage lies in the fact that there is no weight, volume or power penalty to Spacelab.

There is a strong probability that the IBM-developed HITS/ECEP software used in Level IV Payload Checkout and Level III/II Spacelab integration can be adapted to perform the decommutation and packetization functions required in the Minimum Impact System. If so, the same mission-unique software package required for payload checkout could also be used at the SLDPF for mission

operations ECIO data processing. A follow-on study is recommended to ascertain the feasibility and estimate the cost of the minimum impact approach.

5.3 COST ANALYSIS

The results of the cost analysis are summarized in Table 5-1 for three approaches to Spacelab packetization. All cost figures are crude estimates based on the initial definition of requirements. Only the Spacelab and associated GSE and prelaunch costs are estimated. Estimation of the costs of converting the experiments, POCC facility and SLDPF to packets are outside the scope of this study and must be added to obtain total cost estimates. Flight system costs are for delivery of three space qualified flight units plus one spare and one qualification test unit. The costs of integrating the flight unit into Spacelab and incorporating its documentation into the Spacelab configuration management system are included.

The "KSC Prelaunch" cost estimate for the Full System is for the development of a 50 Mb/s packet demultiplexer to replace the HRDM. This figure was obtained by proportioning the HRPM development cost to the HRM-to-HRDM cost. If the full system were actually implemented, it is likely that the POCC and SLDPF would pay for the development of an operational packet demultiplexer. KSC could then purchase an additional unit "off-the-shelf" at a considerable cost saving. Hybrid system costs at KSC are largely for software modifications to the Level IV PCU/ECEP and to the Level III/II HITS software to accept packetized data from the ECIO and SCIO outputs of the HRDM.

The Minimum Impact Approach uses the flight hardware and software as is, resulting in essentially zero flight system cost, as shown in Table 5-1. There may be some KSC costs, depending upon the degree of sophistication at the SLDPF. If a dedicated low rate packetizer is installed in the SLDPF, it may be desirable to modify the HITS/ECEP software at KSC to allow the experimenter to see how his data stream will look at the SLDPF during mission operations. Further study is needed before a specific recommendation can be made and the attendant cost estimated.

Table 5-1. COST ANALYSIS SUMMARY

	IMPLEMENTATION COST ESTIMATES					
	A EXPERIMENTS	B SPACELAB FLT. SYS.	C KSC PRELAUNCH	D POCC	E SLDPF	TOTAL
1. FULL SYSTEM (Phase I)	□	9.0M**	3.1M +	⬡	⬡	○
2. HYBRID SYSTEM (Phase II)	□	2.8M**	0.5M	⬡	⬡	○
3. MINIMUM IMPACT APPROACH	□	0	++	⬡	⬡	○

** - Estimate is for Three Flight Units
+ - Packet Demultiplexer Cost Only
++ - To Be Derived from KSC/SLDPF Study Results
□ - To Be Supplied by Experiment Packetization Study
⬡ - To Be Supplied by Ground Packetization Study
○ - Sum of Columns A through E

APPENDIX A
CURRENT SPACELAB DATA HANDLING SYSTEM

A.1 GENERAL

The Command and Data Management Subsystem (CDMS) is the control element of the Spacelab command and data flow. Figure A-1 provides an overview of the CDMS with respect to the Orbiter and other Spacelab elements.

The primary role of the CDMS is to provide processing functions, services, and electrical interfaces to the various Spacelab experiments. The CDMS hardware and software provides the following basic services to the Spacelab experiments and subsystems:

- Data acquisition and transmission
- Data processing
- Data display
- Activation, command, and control of experiments
- Timing for sequencing/data correlation
- Analog data acquisition
- Closed circuit television
- Audio communication
- Utility support services (control, monitoring & power).

The following subsections describe the hardware, software, experiment data acquisition, and payload services characteristics of CDMS.

A.2 HARDWARE DESCRIPTION

The CDMS functionally consists of a Subsystem Data Bus, an Experiment Data Bus and a High Rate Multiplexer (HRM) subsystem. A block diagram is shown in Figure A-2. The Data Bus System contains three identical computers: an Experiment Computer (EC), a Subsystem Computer (SC), and a Back-Up Computer. The EC and SC share the Mass Memory Unit (MMU) and Keyboard/Display system. The Back-Up Computer is primarily intended as a back-up for the SC and normally contains SC programs; however, it can also serve as the experiment controller in the event of EC failure, by loading EC software from the MMU.

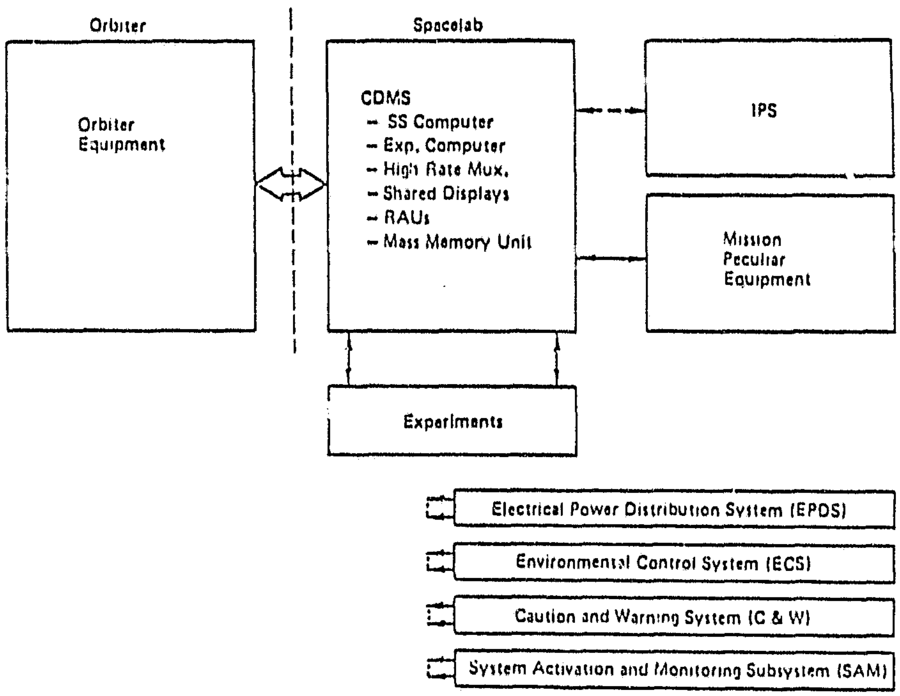


Figure A-1. COMMAND AND DATA MANAGEMENT SUBSYSTEM

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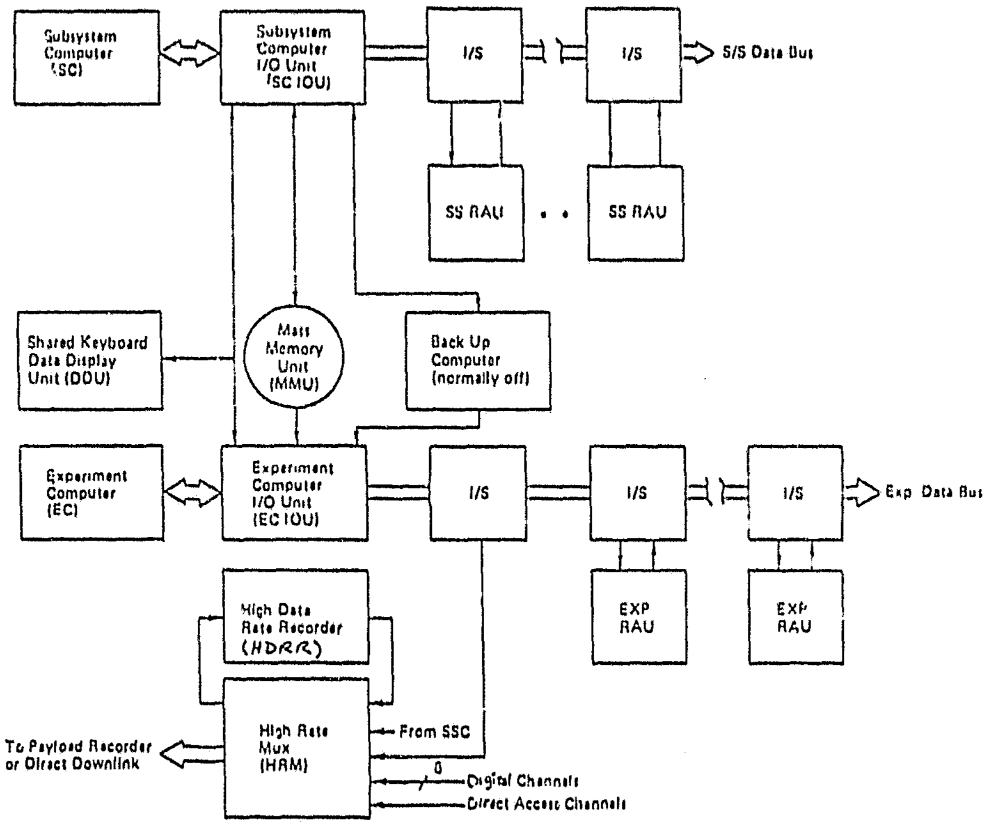

Figure A-2. CDMS BLOCK DIAGRAM

The SC provides control and monitoring of the Spacelab subsystems. This includes powering up the EC and its associated components and monitoring the health/status of these devices in its role as the total Spacelab controller. In addition, the SC performs two essential functions with respect to science instrument operations. First, it controls the formatting and routing of high rate science data via the HRM. Secondly, it performs the monitoring and top level control of the Instrument Pointing System (IPS).

The experiment data management components (computer, I/O Unit, data bus, and RAU modules) are identical to those in the subsystem data management components with the exception of the User Time Clock (UTC) capability, which is unique for experiments.

A.2.1 Computers

The CDMS contains three identical 125 MS computers designed for real-time data processing under severe environmental conditions. The computer has a Fast Arithmetic Operator which provides 200,000 floating point operations per second capability.

The Central Processing Unit (CPU) is microprogram controlled and interfaces with main memory and a Direct Memory Access (DMA) channel which provides a maximum transfer rate of 700K words/second. The CPU interfaces with a peripheral bus (the Minibus), an interrupt system, and a microprogram suspension system which controls input/output. The Minibus is used for the checkout or attachment of various ground peripherals. Summary features of the CPU and its input/output capability are as follows:

- Microprogrammed with built-in Fast Arithmetic Operator (FAO) and direct access memory channel
- Addressing capacity: 1M Bytes (512 K words)
- Arithmetic: binary, 2's complement
- Fast registers: 256 16-bit
- Hierarchical interrupt system: 32 levels
- Variable data representation: binary, fixed point, floating point, character (byte) string

- Addressing modes: 13 direct and indirect
- Processing modes: 3.2×10^5 operations/second (Gibson Mix)
- Inputs/outputs:
  - o parallel
  - o programmed and DMA
  - o 700 K words/sec (DMA)
- Memory:
  - o Core
  - o 18-bit words (16 data-bits, 1 protection-bit, and 1 parity-bit)
  - o Access: byte, word, or double word
  - o Capacity: 64 K words.

A.2.2 Input/Output Unit IOU

All communications between the computers and the rest of the CDMS are handled by the IOUs. They control the transfer of external data into the computer memory and the transfer of data from the memory to all peripherals. The IOU has three interfaces with the rest of the CDMS: (1) RAU and HRM, (2) Digital Display Unit (DDU) and Keyboards, and (3) Mass Memory (Figure A-2). It also has three interfaces with the Orbiter: (1) Multiplexer DeMultiplexer (MDM), (2) PCM Master Unit, and (3) Master Time Unit. Each interface is controlled by a "coupler", which is attached to the non-redundant internal parallel bus of the IOU. All couplers except the "time coupler" are dual-redundant and communicate with other devices via a serial data bus. Only one element of a dual pair is powered at one time.

The interface between the IOU and the prime (and back-up) computer is performed by the redundant DMA coupler. This coupler receives and generates control discretes from and to the computer memory interface and receives and transmits addresses and data over a 16-bit parallel memory bus. The IOU has priority over the CPU memory access and data flow through the IOU is prioritized according to a hierarchy.

A.2.3 Mass Memory Unit (MMU)

The Mass Memory Unit (MMU) is a reel tape recorder for storage of all software for the subsystem and the experiment computers. It enables the CDMS to

reload and/or periodically load the computer memories from the MMU. It stores the data display skeleton formats and pre/in-flight stored experiment tables for usage within experimenter provided programs, and experiment programs that were not contained in the initial program load. Write protection is implemented by software in the MMU handler of the operating system. The user (ECAS) has no control over the write protect since it is all contained in ECOS. The summary MMU characteristics are as follows:

- Total storage capacity: 1.34×10^8 bits
- Read/write speed: 88 inch/sec (2.2 Mb/s)
- Maximum data transfer rate: 500kb/s
- Bit error rate during MMU life: less than 1 in 10^8 bits
- Over 20000 full length tape passes before tape/head wear
- Access Time: Approximately 60 seconds maximum (end-to-end)
- 7-½ seconds for center positioning of data

A.2.4 Data Display System (DDS)

The DDS is the primary on board man/machine interface for the CDMS. It is comprised of the Data Display Unit (DDU) and associated Keyboard (KB). One DDS can be mounted in the Control Center Rack of the Core Segment and one or two in the Orbiter Aft Deck. Another DDS may be mounted in the Experiment Segment.

DDU/KB's are connected to both the subsystem I/O unit and the experiment I/O unit by means of redundant display buses similar to the data buses. Therefore, each DDU can display information from both computers simulataneously and the display format is controlled by software. Each KB can communicate via Subsystem Computer and Experiment Computer by means of a manual switch. Each KB has also the ability to call either subsystem or experiment information for display on any of the three DDU's. This is also controlled by software. The major hardware characteristics of the DDU are summarized as follows:

- Buffer memory: 1024 words of 16 bits
- Available symbols: Alphanumeric (128) and Vectors
- Available positions for symbols: 22 lines of 47 symbol positions
- Size of symbols: 4.8 x 3.2 mm or 7.7 x 5.1 mm
- Refreshing rate: 60 Hz nominal, 30 Hz minimum (overload condition)
- Colors: Red, yellow, green, overbright green.

The KB produces an ASCII code. There are 115 usable alpha-numeric symbols, 1024 different vector lengths, and 4096 different angles. There are a limited number of editing facilities for the operator input line.

A.2.5 High Rate Multiplexer (HRM)

The high rate data acquisition on Spacelab is accomplished by the High Rate Assembly which consists of the HRM and the High Data Rate Recorder (HDRR). The HRM represents the core of the High Rate Assembly, and its functions extend beyond data multiplexing. The HRM also controls the data routing within the on-board part of the High Rate Assembly; it performs the voice digitizing and GMT encoding, and it provides the electrical interface circuits to the on-board equipment. It interfaces with the KU-Band Signal Processor (KUSP) in the Orbiter to accomplish the downlink of high rate data.

The main features of the HRM are:

- Outputs to KUSP: 48 Mb/s, 32 Mb/s to 125 kb/s in binary steps on any of three lines
- Output to High Data Rate Recorder (HDRR): 32-16-8-4-2-1 Mb/s
- Output to Payload Recorder (in Orbiter): 1 Mb/s to 125 kb/s (binary steps)
- Input from HDRR: 32-24-16-12-8-4-2 Mb/s
- Input from Payload Recorder: 1 Mb/s
- Experiment Input Channels (16) Nominal Bit Rates:

at 48 Mb/s HRM output rate	16 Mb/s to 62.5 kb/s
at 32 Mb/s HRM output rate	15 Mb/s to 41.7 kb/s
at HRM output rates < 32 Mb/s	up to actual output rate less the HRM overhead

- Direct Access Channels (2): 50 Mb/s (max)
- CDMS Computer Channels (2): 25.6 kb/s (SC)
51.2 kb/s (EC)
- GMT Channel resolution for HRM output rates:

1 Mb/s	10 ms
1 Mb/s	variable, based on output rate

- Voice Channel Inputs (3): 128 kb/s Total

A.2.6 Remote Acquisition Unit (RAU)

The RAU's are the principal interfaces between experiments and the CDMS for acquisition of low rate digital data, analog data and distribution of commands. The data flow between RAU's and the I/O unit is performed via simplex, (dedicated) serial buses with 1 Mb/s clock rate. Each experiment RAU provides the following capabilities for the user to interface his instrument with the CDMS.

Inputs:
- o 128 flexible differential inputs for analog or discrete signals
- o 4 serial PCM data channels with clocks, code NRZ-L.

Outputs:
- o 64 ON/OFF command channels
- o 4 Serial PCM command channels with associated clocks
- o 4 User Time Clock channels (1024 kHz)
- o 4 User Time Clock update channels, 4 pulse cycles/s

The experiment RAU's are connected to the I/O unit by the experiment bus, which consists of a unidirectional "command line" that carries instructions and data from the I/O unit to the RAU's; and a unidirectional "data line" which carries responses and data from RAU's back to the I/O unit.

Commands and data are transferred in 16-bit words at a 1 Mb/s rate. An additional "clock bus" is also provided which distributes the Master Time Unit (MTU) derived 1024 kHz clock and update pulses from the I/O unit to experiment RAU's for the user. (It should be noted that the subsystem bus connecting the subsystem RAU's to the subsystem I/O unit is similar to the experiment bus except that the "clock bus" is not provided.) Experiment RAU's can be connected to the experiment data bus at a number of interconnecting stations (IS) in the module and on each pallet segment. Each station accommodates two RAU's.

The RAU data acquisition is based on a software controlled concept. The software for Spacelab subsystem data acquisition and control is provided in the Subsystem Computer. The software for experiment data acquisition and control is provided by the experimenter in accordance with his requirements. Applicable portions of the Spacelab software can be used by the experimenter. (Refer to subsection A.3 for a summary of the CDMS software.)

The experiment RAU's are scanned periodically with basic periods of from 10 ms to 1 s. Each scan cycle will be initiated and controlled by the Experiment Computer software. The experimenters may design their own software to generate additional measurement cycles using the operating system task scheduler. This scheduler accepts priority levels and queues up experiment software requests for data and command transmission.

A.2.7 High Data Rate Recorder

The principal function of the High Data Rate Recorder (HDRR) is to provide for intermediate recording of experiment data during interrupted Orbiter to TDRSS transmission times. Besides this, the experimenter may record his experiment or housekeeping data for on-board storage.

The HDRR and the HRM form an integrated system controlled by the Subsystem Computer in a coordinated manner. Experiments interface with the HDRR via the HRM only. During recording of formatted data and reproducing of all data, the HDRR is externally synchronized by the HRM clock. When connected to a DACH channel, the HDRR is synchronized to the experimenter clock received via the HRM.

The HDRR is used as a buffer during TDRSS non-coverage time or Ku-Band modes with bit rates below the HRM output bit rate. During reproduce the recorded data can be interleaved into the real time data stream through a recorder-dedicated input channel of the HRM or directly dumped to the KUSP via the HRM, but independent of the formatter. The HDRR can play back only in reverse.

A.3 SOFTWARE DESCRIPTION

The Spacelab CDMS is controlled by two operating systems, the Subsystem Computer Operating System (SCOS) and the Experiment Computer Operating System (ECOS), which reside in the respective computers. Experiment Computer application programs which are mission unique are referred to as Experiment Computer Applications Software (ECAS).

A.3.1 SCOS

SCOS software originates commands and monitors performance for operation of the Spacelab hardware. The major impact of SCOS to the experiment data flow is in powering up/down experiments and in providing HRM format control.

Formats selected from the Mass Memory Unit (MMU) are transmitted via Data Bus to the HRM where they are executed on SCOS command. A software executing back-up capability exists within SCOS for the hardwired Spacelab C&W Subsystem.

A.3.2 ECOS

The ECOS provides a real-time, multiprogramming operating system to perform hardware resources allocation and application program control/support for the 125 MS computer. It executes the following functions in performing its role in support of experiments:

- IOU Power Control
- Interval Time Support
- I/O Processing
- Telemetry Execution (out-of-limits) Monitoring
- Orbiter MDM Communications
- Dedicated Experiment Processor Communications
- Keyboard Processing
- Display Processing
- Timeline Execution and Maintenance
- Slow Loop Processing (long duration processor control)
- Background Processing Control

ECOS also provides data conversion (numerical, character, string) and error recovery (hardware, software) services for all programs executing in the EC. In addition it provides a collection of routines available to all EC software tasks.

A.3.3 ECAS

The user's software resident in the Experiment Computer is designated Experiment Computer Application Software (ECAS). This software can be written to perform virtually any operations upon his data that the user desires, within EC speed and memory constraints. The software can be written in FORTRAN or 125 MS assembly language.

A.4 EXPERIMENT DATA ACQUISITION AND HANDLING

The current Spacelab data handling system provides two types of paths for acquisition of experiment data: (1) the RAU for low rate data, and (2) the HRM for high rate data. The flow of experiment data is shown in Figure A-3.

Low rate data are sampled by Remote Acquisition Units (RAU's) and transferred to the EC via interconnecting stations (IS's), the experiment data bus, and EC Input/Output Unit (EC IOU). On the same path, serial magnitude commands and discrete (on/off) commands are transferred from the EC to the experiment via the RAU's.

Low bit rate scientific and housekeeping data processed by the Experiment Computer can be transmitted by the Orbiter downlink via the Tracking and Data Relay Satellite System (TDRSS).

Medium and high rate scientific data are acquired by the High Rate Assembly part of the CDMS. This part consists of the High Rate Multiplexer (HRM) which includes a Voice Digitizer, the High Data Rate Recorder (HDRR), and the Orbiter Payload Recorder. This system is able to multiplex up to 16 experiment input channels and data from the SC and EC for direct downlink via the Tracking and Data Relay Satellite System or for recording (HDRR or the Orbiter Payload Recorder) during non-transmission times of the Orbiter KU-Band System. The recorded data may be interleaved with real time experiment data for transmission to ground.

A.4.1 Low Rate Data Acquisition

Low rate experiment data resides in user-provided buffers. The RAU provides the 1 MHz clock used to transfer a maximum of 32 serial data words to the data bus. A 16-bit buffer in the RAU checks word by word parity.

Data from the RAU traverse the data bus through the I/O units and are buffered under control of ECOS. ECOS configures the data as shown in Figure A-4 for transmission via the data bus to the HRM EC port. The low rate data format is transparent to HRM processing when multiplexed with high rate data.

A.4.2 High Rate Data Acquisition

The user delivering serial data to the HRM will, on the ground, recover his data from a High Rate Demultiplexer (HRDM) completely unchanged. This means that the user himself has to take care of the formatting and structuring of his serial

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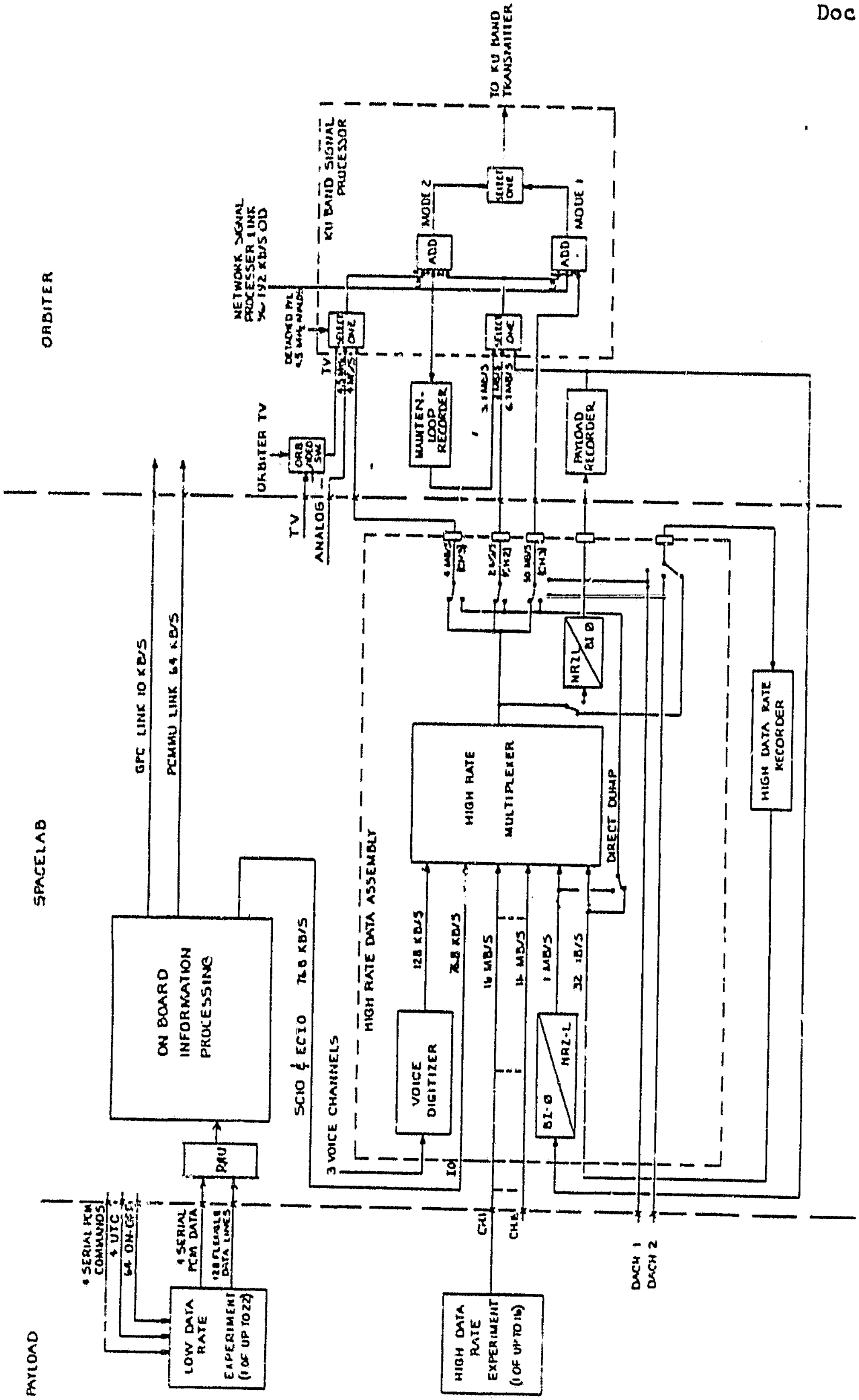

Figure A-3. CURRENT SPACELAB EXPERIMENT DATA ACQUISITION AND HANDLING SYSTEM

160 WORDS

MINOR FRAME	24 BIT	SYNC	FC	SOURCE ID	GML ID	DATA	DATA
	24 BIT	SYNC	FC	MISSION ID		DATA	DATA
	24 BIT	SYNC	FC	GMT DAY	GMT HRS	DATA	DATA
	24 BIT	SYNC	FC	GMT MIN	GMT SEC	DATA	DATA
	24 BIT	SYNC	FC	OPEN	GMT SEC/100	DATA	DATA
	24 BIT	SYNC	FC	CORRELATION WORD		DATA	DATA
	24 BIT	SYNC	FC	DATA		DATA	DATA
	≈	≈	≈	≈		≈	≈
	24 BIT	SYNC	FC	DATA		DATA	DATA

Figure A-4. EC FORMAT TO HRM

data. To facilitate this task, each HRM experiment channel can operate in two different modes:

Normal Mode:

In this mode, the word structure in the HRM output frames are not at all correlated with any structure of the input data. The serial input data are arbitrarily chopped into 16-bit words for parallel processing inside the HRM. Consequently, the user has to insert some kind of sync pattern into his serial input bit stream, in order to be able to extract on ground his scientific data out of the serial bit stream of his output channel.

Word Pattern Transparency Mode:

In this mode, the input data can be structured in words that, after multiplexing, can be identified as words in the HRM output frames in those positions determined by the chosen format. Synchronously with the frame or format pulse, which indicates the beginning of a new frame or format respectively, experiment data can be delivered to the HRM in bursts of 16-bit words. Because the clock counter is reset at the beginning of each format, these words are identical to the internal words the HRM handles in parallel. The HRDM in this mode delivers the data words without bit rate smoothing at the nominal bit rate allocated to the particular experiment channel.

The mode of each HRM input channel is selected by an external HRM connector. This connector is programmed by hardwired jumpers on a mission-to-mission basis. It should be noted that in the word pattern transpapency mode the words are delivered as 16-bit bursts and not as a continuous bit stream. This has to be taken into account for further on-ground data handling because it might rule out the use of standard ground decommutation and recording equipment.

High rate experiment data is clocked (by the user) into an HRM input channel as shown in Figure A-5. The ÷16 register is reset and a format pulse made available to the user each time 16 bits of data are clocked into the the HRM. Four words of input buffering are provided for each channel to aid in format building. The output format of the HRM is shown in Figure A-6. Alternating SYNC or status headers are written into the first two 16-bit word positions of each HRM frame. The line words are sequentially transferred to a shift register for serial transmission to the KUSP.

Changing of HRM/HRDM formats requires close time-line coordination between onboard and ground-based systems to minimize loss of data to experiments not affected by the change. The problem is more complex if an HRM bit rate change occurs as a result of the new format. In this case, the configuration of all frequency-sensitive components in the data flow (such as bit synchronizers) has to be changed. In some cases the operating mode of the KUSP also has to be changed.

A.4.3 HRM Data Handling Services

In addition to the items described in the preceeding subsection, the HRM also provides the following services to the payload (Refer to Figure A-3):

- Outputing of multiplexed data stream to the 2, 4 or 50 mb/s ports of the KUSP
- Outputing of the multiplexed data stream to either the HDRR or the Orbiter Payload Recorder
- Interleaving of reproduced (playback) data from either recorder into the live data stream
- Direct dump of either recorder to the KUSP
- Outputing of either Direct Acess Channel (DACH) to the KUSP
- Outputing of either DACH to the HDRR.

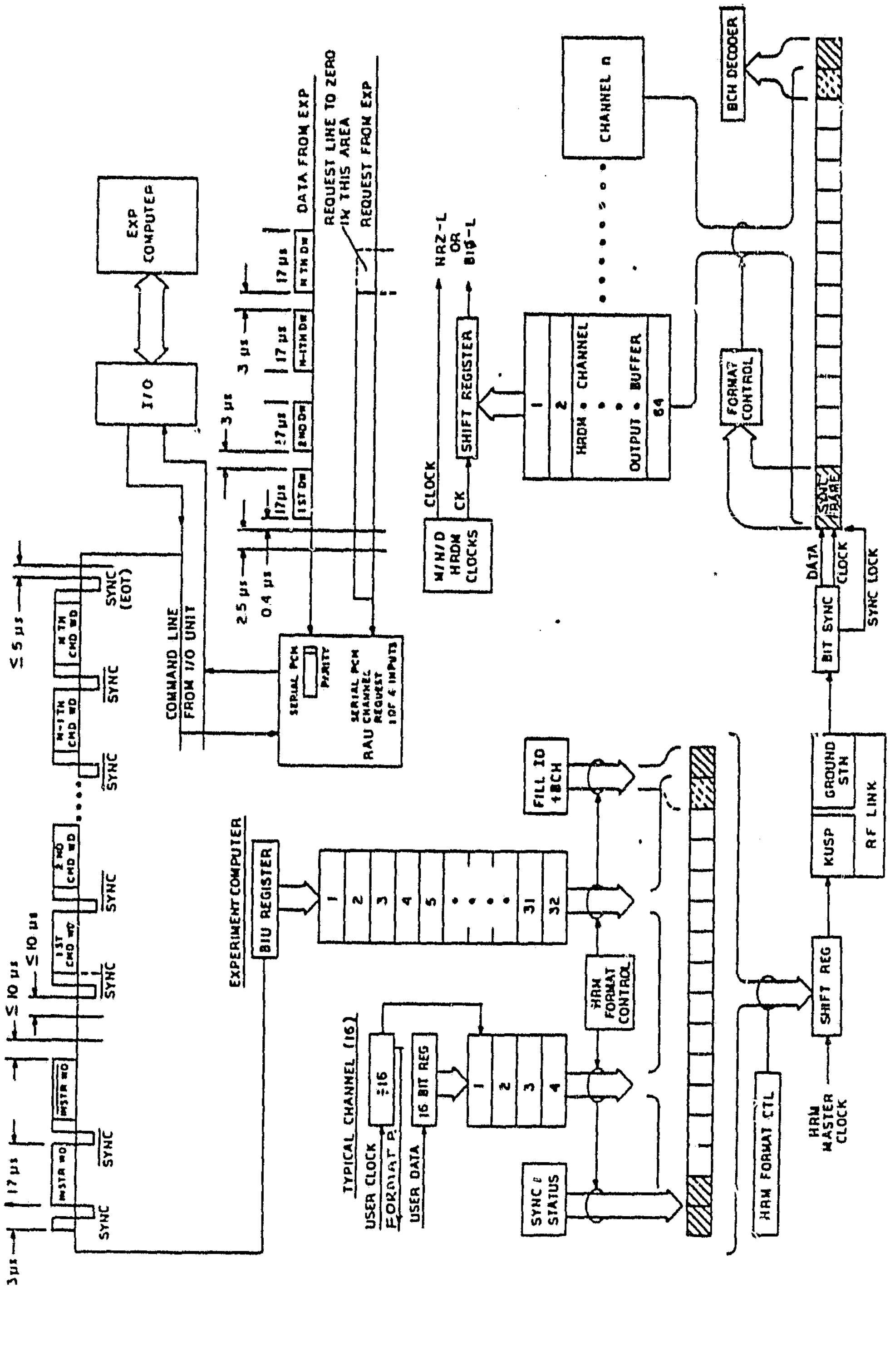

Figure A-5. HRM DATA FLOW

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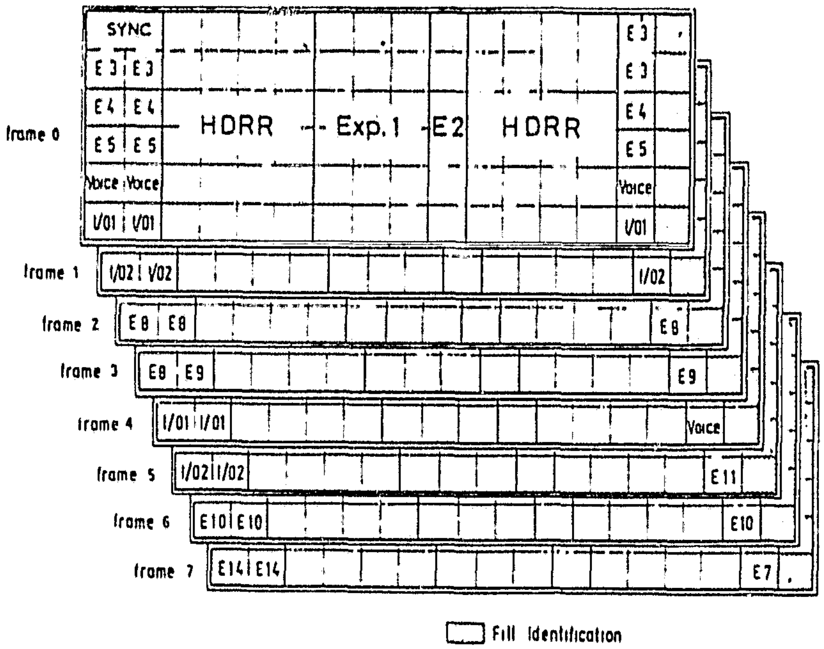

Figure A-6. EXAMPLE OF HRM FORMAT

A.5 PAYLOAD SERVICES

The CDMS services and interfaces provided to the experimenter are essentially the same whether or not the Spacelab is flown in the Module or Pallet-Only configuration. On board, display support in the Pallet-Only mode is provided by locating a DDS in the Orbiter Aft Flight Deck.

Mission unique requirements are accommodated by addition of up to 21 experiment RAU's, flexibility of HRM data rates, modes, and formats, and mission unique software application programs (ECAS).

ECOS can support up to eight core-resident application programs at one time and exchanges (overlays) the programs from the MMU as necessitated by the mission timeline. Scheduling of experiments and ECAS can be accomplished by ECOS timeline services.

Ground monitoring of experiments is performed via Experiment Computer-acquired low rate data (< 5Kb/s) and directly acquired high rate data via the HRM/KUSP. Both types of data may be extracted (on the ground) from the KUSP 50Mb/s composite data stream. Both types are recorded on board during times with the downlink is not availaible.

Direct downlink of high frequency (dc to 4.5 MHz) analog or video signals is also provided by the CDMS for experimenter control and real time evaluation. Additionally, three voice channels can be digitized and downlinked as part of the HRM composite output.

Experimenter uplink commands from the POCC are routed via the MCC and GPC to the CDMS for experiment control, timeline command sequence loads and ECAS communication.

Onboard experimenter control/monitor functions are performed by the on-board crew who has access to the displays and keyboards (DDS). In conjunction with the DDS, the EC supports the examination of experiment data via experiment-unique display pages and the issuing of commands from the alphanumeric and functional keyboards. Using the DDS, the experimenter can transfer software from the MMU to the EC or to a DEP.

Timing is available to the experiments for correlation of data. Mission Elapsed Time (MET) from the Orbiter is also provided for the experimenter. Also provided are the 1024 kHz User Time Clocks (UTC) with 4 Hz updates. The UTC's are routed through the CDMS to the experiment RAU interface.

NASA, in conjunction with the experimenter, determines the extent of CDMS monitoring of experiments by the Caution and Warning System.

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APPENDIX B

GEORGE C. MARSHALL SPACE FLIGHT CENTER
MARSHALL SPACE FLIGHT CENTER, ALABAMA 35812

STANDARD

PAYLOAD OPERATIONS CONTROL CENTER FORMAT STANDARD

1.0 PURPOSE AND SCOPE

This standard defines the characteristics and constraints on telemetry format structure for those telemetry data streams (or portions of telemetry data streams) required to be processed by the Payload Operations Control Center (POCC) at Johnson Space Center. Those experiments requiring POCC support must meet this Standard. In addition, a set of recommendations for optimizing experiment data decommutation and processing is incorporated in the Standard. The user may ignore these recommendations and still be in compliance with the Standard.

Telemetry data streams requiring POCC recording and transmission to experiment provided Ground Support Equipment need only to meet the POCC telemetry standards for bit rate (paragraph 1.2.1), minor frame length (paragraph 1.2.3.b), and frame synchronization pattern length (paragraph 1.2.3.d).

The characteristics of the bit stream required by the radio link are not included in this standard because POCC requirements are limited to handling demodulated, bit synchronized, NRZL data stream and associated clock. Standards for error encoding are not included because there are no POCC requirements to perform error decoding. Standards for time tags within the experiment data streams are not included because POCC processing will use either the Spacelab's High Rate Demultiplexer (HRDM) time tag or the POCC receipt time tag.

A composite set of format standards relative to the High Rate Multiplexer and ground data processing is contained in the "Spacelab High Rate Multiplexer (HRM) Format Standards." The standard as specified herein imposes some more restrictive specifications on the telemetry format structure to allow POCC processing. If these standards are met, the standards specified in the reference document will be met.

1.1 Definition of Terms — This section provides definitions of telemetry terms as used in this standard.

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(a) Telemetry data stream — A continuous single serial bit stream of time division multiplexed data.

(b) Format — The general arrangement of the data in a telemetry data stream. Each format shall have a pre-established bit rate, frame size, word size, commutation sequence, measurement set and frame overhead (synchronization pattern, frame counter, experiment identifier, time words, etc.). See Figure 1.

(c) Major Frame — Includes more than one minor frame. The length of a major frame is defined as the number of minor frames necessary to include at least one sample of all measurements for this format. See Figure 1.

(d) Minor Frame — A recurring fixed integer number of words which includes a single synchronization pattern. See Figure 1.

(e) Minor Frame Counter — A single binary word which is included in each minor frame to uniquely identify the frames position in the major frame sequence. The counter should increment by one for each new minor frame with a starting value of zero for the first minor frame in a major frame. The minor frame counter shall occupy the same word position in every minor frame.

(f) Word — An integral subdivision of the minor frame defining the basic package size for measurements for this telemetry data stream. See Figure 1.

(g) Parameter/Measurement — A group of contiguous bits less than or equal to 64 bits whose pattern represents the value of the data point.

(h) Syllable — A measurement whose length requires two or more words. is said to have syllables. A single syllable is equal to a word. An example of a multi-syllable measurement might be spacecraft time.

(i) Commutated data — That data which is sampled only <u>once in a minor frame</u>. See Figure 1.

(j) Super-commutated data — That data which is sampled <u>more than once in a minor frame</u>, submultiple frame or sub-submultiple frame. See Figure 1.

(k) Subcommutated data — Data which is multiplexed at sample rates which are submultiples of the minor frame rate or when <u>several minor frames are required to generate a complete measurement set</u>. See Figure 1.

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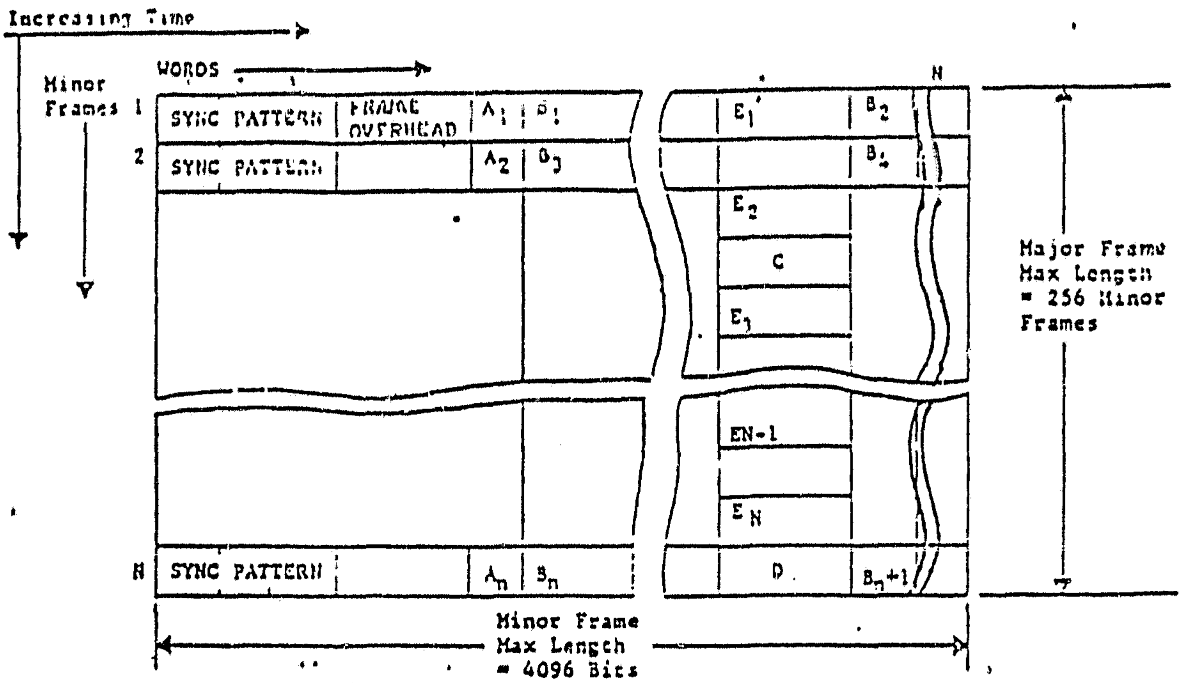

A_N — Example of normal commutation — one sample in each minor frame.

B_X — Example of a super com — the time interval between samples B_1 and B_2, B_2 and B_3, B_3, and B_4, B_n and B_n+1 is identical.

C& D — Examples of a subcom — C and D have less than one sample per minor frame.

E_X — Example of super commutation a subcom — the time interval between samples E_1 and E_2 and E_2 and E_3 - . . . EN-1 and E_N are identical.

Figure 1

1.2 Telemetry Standards — Telemetry data streams (PCM data) shall be transmitted as serial binary-code time division multiplexed samples, using a sequence of bits within each sample to represent a discrete magnitude of the data samples. This standard defines the allowable data format (including the word, minor frame and major frame characteristics) and structure of the data to be displayed and processed in the POCC.

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1.2.1 Bit Rate — The telemetry data streams to be processed by the POCC shall be greater than 200 bits/sec and less than or equal to 2 Megabits/sec.

Routed telemetry data streams in the POCC shall be greater than 200 bps and less than 50 Mbps. The telemetry data streams to be recorded by the POCC shall not exceed 50 Mbps and the minimum data rate shall not be less than 200 bps. Variations of the telemetry data stream clock rate shall not exceed 2.0 percent of the normal rate during any processing period.

1.2.2 Format Structure — The measurements on each telemetry data stream shall be organized into an indentifiable format. Each format shall have a pre-established bit rate, a pre-established commutation sequence of a pre-established measurement set and identification bits (synchronization pattern, frame counter, etc.).

(a) Format Identification — Each format shall contain a measurement which identifies the format being transmitted. All measurements within the format shall be unambiguously identified by the use of the format identification, the minor frame counter, and established frame commutation sequence (word location within the minor frame). All experiments with a multi-bit rate capability (identical commutation sequence at a higher or lower bit rate) shall include either a mode ID which uniquely identifies each bit rate or a separate bit rate identification measurement in each major frame.

It is recommended that each experiment telemetry data stream include an experiment identification measurement to insure positive identification of data during processing.

(b) Format Change — It is recommended that changes between formats be effected at a time corresponding to the leading edge of the first minor frame sync word belonging to the first major frame which will contain the new format. Where format changes occur relatively frequently, it is recommended that error protection, such as parity, be provided for the format identifier, to insure positive identification of the data.

1.2.3 Frame Structure — The frame overhead (synchronization pattern, minor frame counter, experiment ID, format ID, bit rate ID, command verification, spacecraft clock, etc.) and parameter measurements transmitted in each telemetry format shall be further organized into sequences of identifiable digital words termed a minor frame. The synchronization pattern and frame counter must appear in every minor frame. The other frame overhead may appear as infrequently as once per major frame. Refer to Figure II.A.1.-2. The minor

frame shall be subdivided into words, beginning with the first bit of the frame synchronization pattern. Measurements shall be multiplexed so that the beginning of every measurement is coincident with the word structure. Data from different measurements shall not be interleaved on a bit-by-bit basis or other nonword oriented basis; however, single-bit on-off indicators may be assembled in predetermined order into words for transmission.

(a) Major Frame Format — The maximum length of a major frame shall be 256 minor frames and the minimum frame length shall be four minor frames. For a given format all subcommutator cycle durations shall be integer submultiples of the major frame cycle duration, and the phasing of the subcommutators shall be fixed and synchronized to the major frame, so that a single minor frame counter will unambiguously identify the position of all measurements in the major frame format.

(b) Minor Frame Length — Each PCM frame shall contain a fixed number of bit intervals, all of equal duration. Minor frame length is the number of bits appearing between successive occurrences of the leading edge of the first bit of the frame synchronization word.

(1) The length of each minor frame shall be an integer multiple of 8 bits.

(2) The minimum minor frame length shall be at least 4 words after the frame synchronization bits.

(3) The maximum minor frame length shall be 4096 bits.

(4) A given format shall use only one minor frame length and one word length.

(5) It is recommended that unused words within a format shall be distributed so as to minimize the probability of long sequences of consecutive ones or zeros.

(c) Frame Rate — The minor frame rate shall not exceed 1024 frames per second.

(d) Frame Synchronization Pattern — Each minor frame shall begin with a frame synchronization pattern. The frame synchronization pattern for Spacelab shall be octal 76571440 and shall appear in the first 24 bits of each minor frame.

(c) Frame-Sequence of Data — The format shall be structured so as to permit symmetrical super commutation applying to major and minor frames; i.e., minor or major frame words must be assignable to a given measurement so that sampling at regularly spaced intervals is possible. (See examples "A" and "E" in Figure 1.) It is recommended that the frame overhead (the minor frame counter, experiment ID, format ID, command verification bit rate ID and spacecraft clock) appear at fixed positions immediately following the frame synchronization pattern.

1.2.4 <u>Word Structure</u> — In those cases where the PCM telemetry word represents a single measurement, the sign bit (if used) shall appear first, followed by the magnitude bits in sequential decreasing order, most significant bit (MSB) first and least significant bit (LSB) last.

Sign (if used)	MSB	Data Bits	LSB
		(increasing time)	

The telemetry words shall be an integer multiple of 8 bits in length. If multi-syllable words are used, the most significant syllable shall be transmitted first. It is recommended that multi-syllable words be placed in contiguous minor frame word locations. It is recommended that 8-bit words be used. Parameter length includes sign bit and magnitude bits. Other status bits, short length registers, and other bilevel measurements shall be grouped together into status words whose length is an integer multiple of the telemetry word size. There shall be only one word length within a particular format.

1.3 <u>Decommutation Limitations</u> — There are limitations to the number of words that can be extracted from a format which are imposed by the commercially available decommutation units presently baselined for the POCC. The limitation is a function of the number of minor frames in a major frame, the number of words in a minor frame and the number of subcommutated words to be extracted. To avoid or minimize the affect of this limitation, it is recommended that subcommutated parameters that are required to be processed by the POCC be loaded in the same word(s) in each minor frame.

1.4 <u>Exceptions</u> — Each user of the data system shall make every effort to conform to these standards. When the experiment mission requirements cannot be met with a standard system (one that is in complete comformance with these standards), an exception may be requested for assessment.

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(a) The features that are believed to be nonstandard and the technical reasons for their use will be identified. An analysis will be provided of the system and its operation with specific reasons why a standard system cannot meet the experiments mission requirements.

(b) The exception request will be assessed for implementation compatibility. Resulting costs and/or schedule impacts will be provided for programmatic decisions.

C-2

APPENDIX C.
REFERENCES

1. Guideline 3.3, "Space Data Packetization", Issue 1979-11-05, Goddard Space Flight Center, Greenbelt, MD, November, 1979.

APPENDIX D
ABBREVIATIONS

ACCU	Audio Central Control Unit	B
ASCII	American National Standard Code for Information Interchange	
ATE	Automatic Test Equipment	
BI-Ø	Bi-Phase Logic	
CASS	CDMS Analysis Support Software	
C&T	Communication & Tracking	
C&W	Caution & Warning	
CDMS	Command and Data Management Subsystem	
CDR	Critical Design Review	
CD & SC	Communications Distribution & Switching Center	
CID	Computer Interfacing Device	
CITE	Cargo Interface Test Equipment	
CRC	Cyclic Redundancy Code	
DACH	Direct Access Channel	
DDU	Data Display Unit	
DDS	Data Display System	
DDSS	Data Display System Simulator	
DMA	Direct Memory Access	
EC	Experiment Computer	
ECAS	Experiment Computer Applications Software	
ECEP	Experiment Computer Equipment Processor	
ECIO	Experiment Computer Input/Ouput	
ECOS	Experiment Computer Operating System	
ECS	Environmental Control System	
EDB	Experiment Data Bus	
EMS	Electromagnetic Compatibility	
EOF	End of Frame	
EPDS	Electrical Power Distribution System	
FAO	Fast Arithmetic Operator	
FC	Frame Count	

APPENDIX D
ABBREVIATIONS (CONT'D)

B

FIFO	First-In-First-Out
GFE	Government Furnished Equipment
GML	General Measurements List
GMT	Greenwich Mean Time
GPC	General Purpose Computer (Orbiter)
GPU	Ground Power Unit
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HDR	High Density Recorder
HDRR	High Data Rate Recorder
HITS	HRM I/O Test System
HMT	High Rate Multiplexer Test (Rack)
HRDM	High Rate Demultiplexer
HRM	High Rate Multiplexer
HRMTS	HRM Test Station
HRPM	High Rate Packet Multiplexer
IOU	Input/Output Unit
IDT	Instrumentation Data Tape
I/F	Interface
IPL	Initial Program Load
IPS	Instrument Pointing System
IRIG	Inter-Range Instrumentation Group
IS	Interconnect Station
JSC	Johnson Space Center
K b/s	Kilobits per second
KB	Keyboard
KG	Kilogram
KSC	Kennedy Space Center
KUSP	Ku Band Signal Processor (Orbiter)

APPENDIX D
ABBREVIATIONS (CONT'D)

B

KUSP-IS	KUSP Interface Simulator
LSB	Least Significant Bit
LWH	Length, Width, Height
M b/s	Megabits per second
MCC	Mission Control Center
MDM	Multiplexer Demultiplexer (Orbiter)
MDTSCO	McDonnell Douglas Technical Services Company
MET	Mission Elapsed Time
MILA	Merritt Island Launch Area
MS	Milliseconds
MSB	Most Significant Bit
MSFC	Marshall Space Flight Center
MTU	Master Time Unit
NASA	National Aeronautics and Space Administration
NRZ-L	Non-Return-to-Zero Logic
O&C	Operations & Checkout (Building)
OMRSD	Operations and Maintenance Requirements Specification Document
OPF	Orbiter Processing Facility
PC	Printed Circuit
PCM	Pulse Code Modulation
PDM	Packet Demultiplexer
PCMMU	PCM Master Unit (Orbiter)
PCU	Payload Checkout Unit
PDM	Packet Demultiplexer
PDR	Preliminary Design Review
PLR	Payload Recorder (Orbiter)
PRR	Preliminary Requirements Review
POCC	Payload Operations Control Center
RAU	Remote Aquisition Unit
ROM	Rough Order of Magnitude

APPENDIX D
ABBREVIATIONS (CONCLUDED)

s	Seconds
SAM	System Activation and Monitoring Subsystem
SC	Subsystem Computer
SCIO	Subsystem Computer Input/Output
SCOS	Subsystem Computer Operating System
SDR	Signal Distribution Rack
SL	Spacelab
SLDPF	Spacelab Data Processing Facility
SPAH	Spacelab Payload Accomodations Handbook
SPCDS	Spacelab Payload Command & Data System
SR&QA	Safety, Reliability and Quality Assurance
STE	Special Test Equipment
TBD	To Be Determined
TDRSS	Tracking and Data Relay Satellite System
T F/S	Transport Frames/per second
UT	Unit Tester
UTC	Universal Time Clock
VABR	Vehicle Assembly Building Repeater
VDC	Volts, Direct Current
μP	Microprocessor

B

APPENDIX E
IMPACT OF SPACELAB PACKETIZATION TO KSC FACILITIES AND OPERATIONS

E.1 SUMMARY

There is no impact to Kennedy Space Center (KSC) facilities or operations if either the "Minimum Impact Hybrid" or the "Ground Hybrid" version of the Spacelab Packet Data System as defined in Reference 2, Appendix C is implemented. This appendix describes the KSC support facilities for the Spacelab Command and Data Management System (CDMS) and explains why there is no impact.

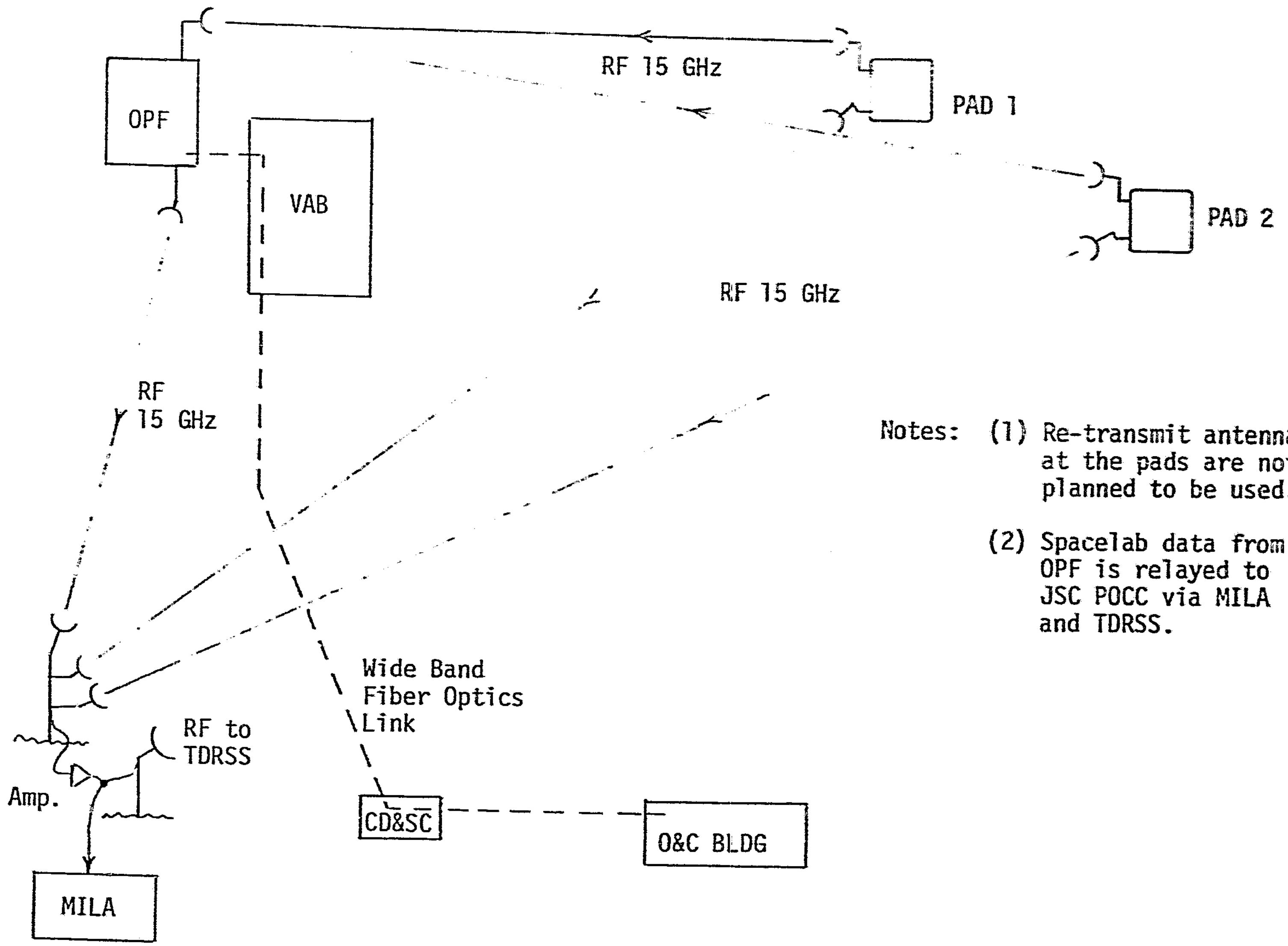
E.2 INTRODUCTION

Spacelab integration and checkout at KSC emphasizes:

(1) integration of individual payloads into a total Spacelab
(2) checkout of a complete Spacelab flight assembly, and;
(3) integration of the Spacelab flight assembly into an Orbiter.

These activities are referred to as Level IV, III/II and I, respectively. The following description is directed to the Spacelab CDMS and to that portion of Ground Support Equipment (GSE) which supports CDMS data managment during KSC test and integration activities. Figure E-1 shows an overview of the facilities under discussion. Summary descriptions of all of these facilities are included for completeness.

The integration process begins in the Operations and Checkout (O&C) Building, which houses the Level IV, Level III/II and Cargo Interface Test Equipment (CITE) test stands. The fully integrated Spacelab flight configuration is transferred to the Orbiter Processing Facility (OPF) for integration with the Orbiter. There is a wideband fiber optics link from the OPF to the O&C Building for monitoring of the CDMS within the Orbiter cargo bay. In addition the Orbiter while in the OPF can communicate with the Payload Operations Control Center (POCC) at the Johnson Space Center in



Notes: (1) Re-transmit antennas at the pads are not planned to be used.

(2) Spacelab data from OPF is relayed to JSC POCC via MILA and TDRSS.

Figure E-1. KSC DATA HANDLING SYSTEM

Houston, Texas. The Ku Band transmitter output goes to an antenna on the roof of the OPF and is radiated to the Merritt Island Launch Area (MILA) communications center approximately four miles away. The RF signal is amplified and transmitted via the Tracking and Data Relay Satellite System (TDRSS) to White Sands, New Mexico, and from there to the POCC.

There are also re-transmit antennas at each of the launch pads, but their use is not planned.

E.3 O&C BUILDING OPERATIONS

A total of five test stands are located in the high bay area of the O&C Building, as shown in Figure E-2. High rate and Experiment Computer Input/Output (ECIO) data can be routed from any of the test stands to three user rooms located on the fourth floor. Patching of data paths is performed in Room 1263 for copper as well as fiber optics lines. Room 1263 also contains a High Rate Demultiplexer (HRDM) and a High Density Recorder (HDR) for use by the Level IV stands. The ECIO data stream can be decommutated for up to eight simultaneous users by the HRM I/O Test System/Experiment Checkout Equipment Processor (HITS/ECEP) located in Room 3259.

E.3.1 Level IV Operation

Level IV accomplishes the functional test and validation of experiment racks, rack and floor assemblies, and pallets within the flight configuration. Experiment flight racks are installed in a level IV test stand located at the west end of the high bay area. The experiments are connected to test stand-provided flight type Remote Acquisition Units (RAU's) and a High Rate Multiplexer (HRM), as shown in Figure E-3. The RAU's function as remote terminal units for the 1 Mb/s bi-directional Experiment Data Bus (EDB), which is connected to the Payload Checkout Unit (PCU) in Room 3259.

The PCU contains a Mitra 125 computer which is the ground version of the CDMS 125MS flight computer. The Mitra 125 functions as the Experiment Computer for Level IV checkout and executes all of the EC flight software. Three remote terminals (DDSS) are connected to the Mitra, one in

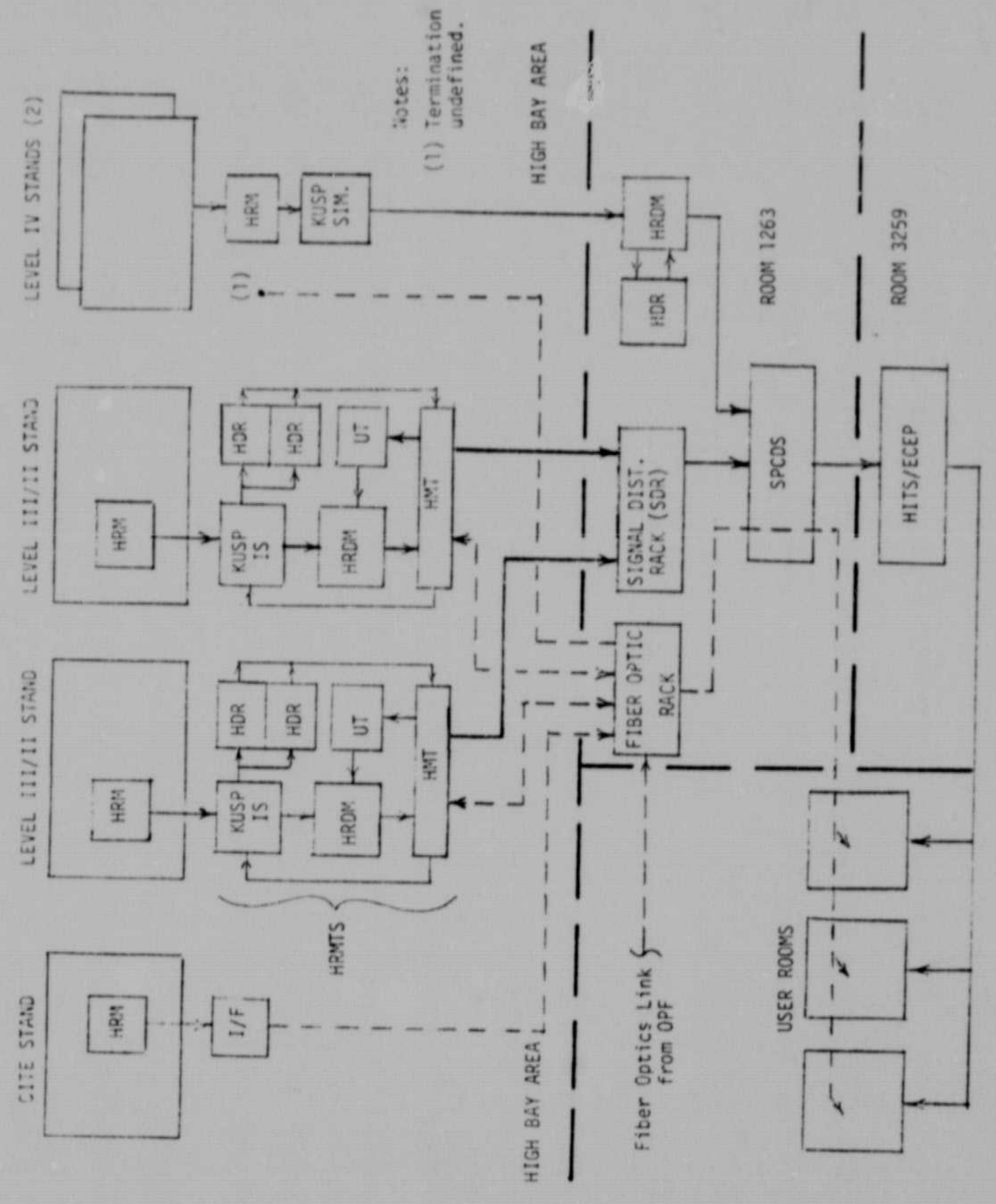


Figure E-2. O & C BUILDING SUPPORT

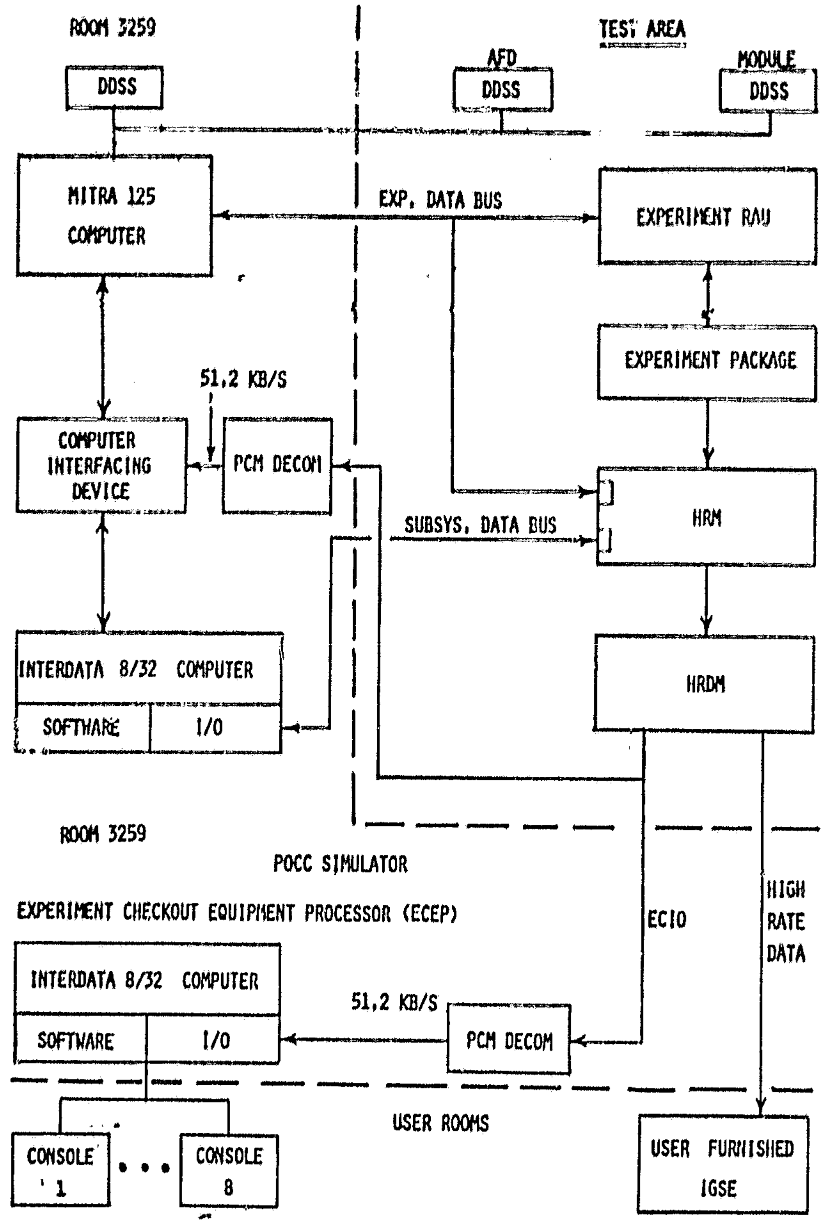


Figure E-3. LEVEL IV TEST CONFIGURATION

Room 3259 and two in the high bay area. The two in the high bay area are used to represent the DDSS flight units located in the Orbiter Aft Flight Deck (AFD) and the Spacelab module. In addition the PCU contains an Interdata 8/32 computer which simulates the remaining intrefaces needed by the EC. The PCU provides data to the EC representing data transfers from the Orbiter General Purpose Computer (GPC), the downlink telemetry (PCMMU), Mass Memory Unit (MMU) and Time Unit (GMT).

The PCU is also connected by a 1 Mb/s bi-directional data bus to the Subsystem Computer (SC) port of the HRM. The PCU utilizes this data bus to simulate HRM format control commands and status activity normally provided by the SC.

The PCU processor decommutates the ECIO data for display (5 consoles), printing or storage (2 tapes), providing the user his first hardware-in-the-loop operation with the Spacelab command and data handling systems.

Low rate data acquired by the RAU's from various experiments is transmitted over the EDB to the Mitra 125. The 125 formats experiment data and other ancillary data into the ECIO downlink format which is in turn transmitted over the EDB to the EC input port on the HRM. High rate experiment data goes directly to the HRM from the generating experiment.

The three HRM output channels are connected to a Ku Band Signal Processor Interface Simulator (KUSP-IS) which routes the output to the HRDM and High Density Recorder (HDR) (2-50 Mb/s) located in room 1263. The output (NRZ-L + clock) from channel 21 of the HRDM, containing the RAU-acquired experiment data (ECIO format), is routed through the Spacelab Payloads Command and Data System (SPCDS) to special interfaces with the PCU and the Experiment Checkout Equipment Processor (ECEP). ECEP, which shares Room 3259 with the PCU, is an Interdata 8/32 processor programmed to simulate the real-time display of ECIO data at the POCC.

All data and control circuits between Room 3259 and the Level IV test stands are provided via the SPCDS distribution patch panels located in

Room 12.. Also ECEP data from Room 3259 is available to the user rooms and to the SPCDS distribution facility. The user rooms, containing user-provided Instrument Ground Support Equipment (IGSE), have access to each HRDM output channel (NRZ-L + clock @ 16 Mb/s or less) via SPCDS. Multiple, flexible and redundant circuits are available between most test elements.

The ECEP configuration provides KSC Level IV with a simulation of JSC POCC operation. RAU-acquired experiment data which meets MSFC-STD-630 (Spacelab High Rate Multiplexer Format Standards) may be displayed during Level IV at any of the eight ECEP consoles. HRM channel data not meeting STD-630 must be routed (via SPCDS) to user IGSE within the user rooms for processing.

The HRM I/O Test System (HITS), also a POCC simulator, can be configured to support Level IV activities; however its primary function is to support HRM testing during Level III/II. (See Section E.3.2).

E.3.2 <u>Level III/II Operation</u>

Level III/II combines, integrates and checks out all experiment mounting elements (e.g. racks, rack sets and pallet segments) from Level IV with the previously installed Spacelab flight subsystem support elements (i.e., core segment, igloo). Two Level III/II Spacelab stands are located just east of the Level IV stands within the high bay area of O&C Building. Operations within Level III/II are based on computer-controlled Automatic Test Equipment (ATE) augmented by the Orbiter Interface Adapter (OIA) and a Ground Power Unit (GPU). These elements constitute the Spacelab Electrical Ground Support Equipment (EGSE). The EGSE-ATE system, located in Room 3247 or 3251, issues Orbiter-type commands and processes Spacelab response, utilizing the SPCDS distribution terminal.

The Spacelab under test communicates with the outside world via simulated Orbiter I/O links. A definition of all the interface signals may be found in ICD-2-05301, Appendix B. The high rate data normally downlinked via the Orbiter KUSP is routed to a KUSP simulator located adjacent to the test stand (Figure E-4).

Each output channel (50/4/2 Mb/s + clock) from the flight HRM mounted in the test stand is connected to the High Rate Multiplexer Test Station (HRMTS) located adjacent to the stand. The HRMTS contains a KUSP Interface Simulator, HRDM, HRDM Unit Tester (UT), two HDR's and a High Rate Multiplexer Test (HMT) Distributor rack. The HMT Distributor provides access to 70 copper lines connecting the HRMTS to a Signal Distribution Rack (SDR) in Room 1263.

Typically, 16 channels + clock of experiment data, ECIO + clock, SCIO + clock, GMT + clock, Format Status, voice analog, IRIG timing, sync status and HDR (PCM + clock) playback are transmitted by this network. The 16 channels of experiment data are routed to the fourth floor user rooms for processing.

The ECIO (channel 21) is routed to HITS for decommutation and display (8 consoles), printing or tape (2) storage. Decommutated experiment data and the full ECIO stream are available in the user rooms.

E.3.3 <u>Cargo Integration Test Equipment (Cite) Operations</u>

CITE provides a high fidelity Orbiter/cargo interface which will be used to support checkout of Spacelab prior to installation in the Orbiter. A flight-type Orbiter GPC and KUSP, located on the CITE stand in the east end of the high bay area, provide a flight configuration interface with the Spacelab CDMS. Functionally, the flight GPC & KUSP provide for a higher fidelity CDMS signal environment.

Test activities are directed from a 3rd floor control room. Data from the HRM is routed to the flight KUSP and to a fiber optics driver (Figure E-5). The optical signal is routed via Room 1263 to the Level III/II HMT where it is converted back to an electrical signal. Data handling and analysis downstream from that port are identical to Level III/II. The 15 GHz output from the KUSP is routed to an antenna on the roof of the O&C Building and on to the JSC POCC via MILA and TDRSS.

E.4 ORBITER PROCESSING FACILITY (OPF) OPERATIONS

Upon completion of CITE testing the fully integrated Spacelab is

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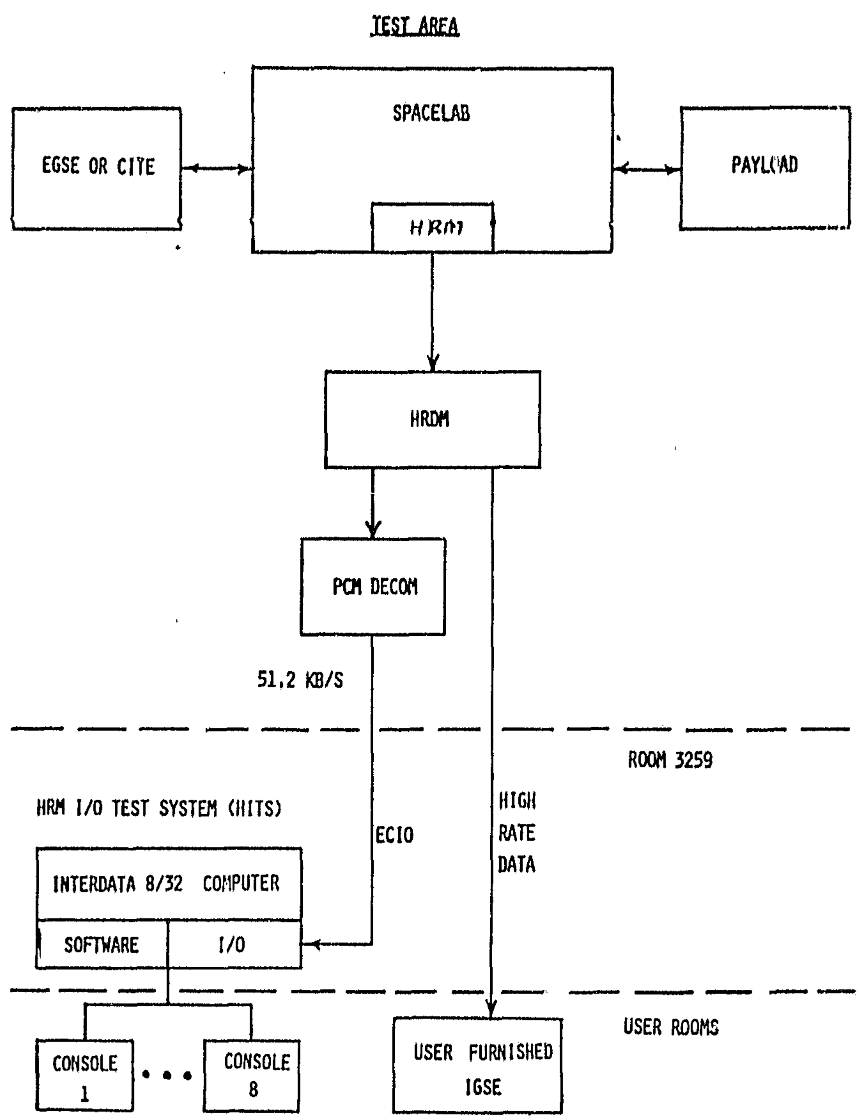
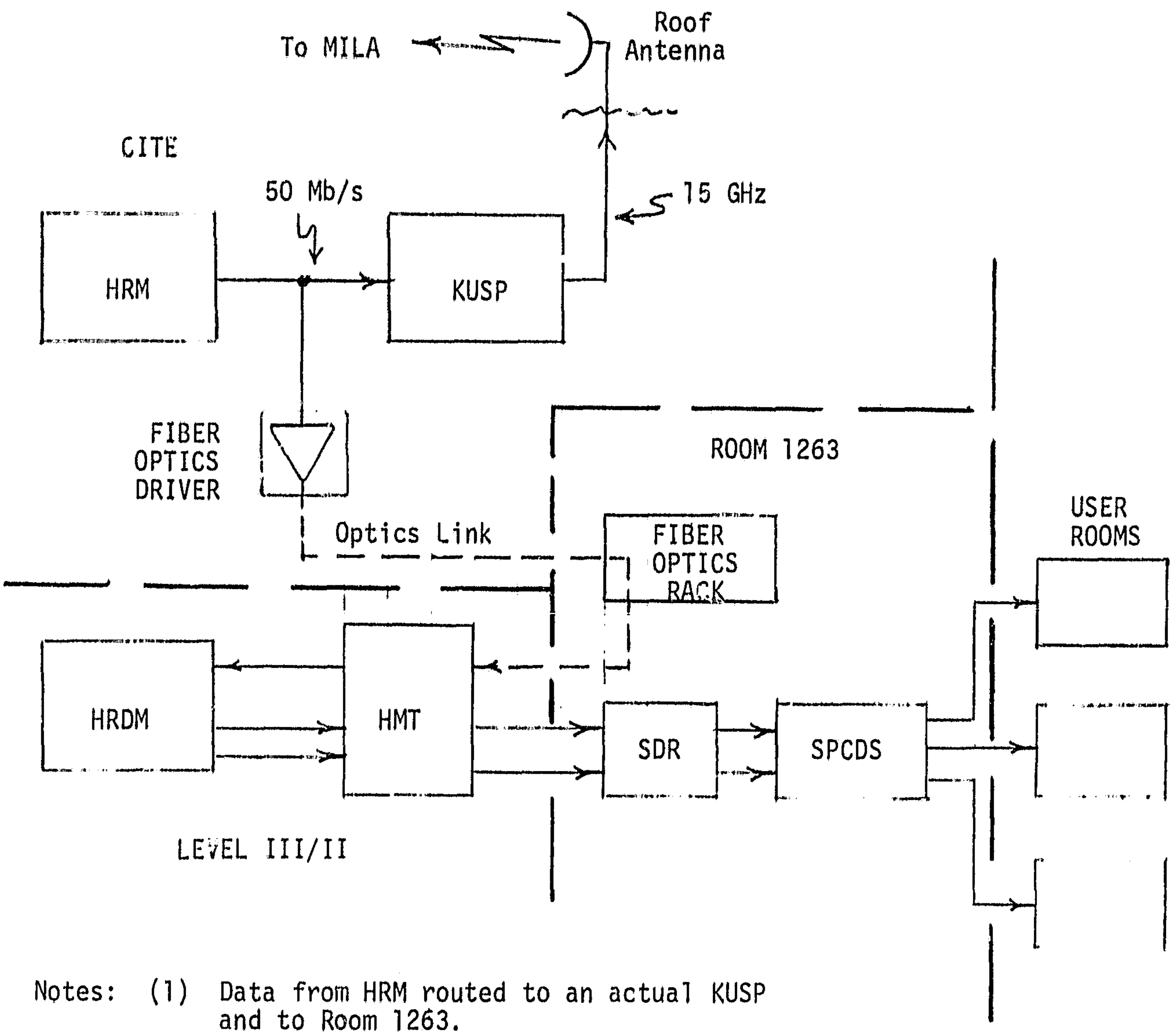


Figure E-4. LEVEL III/II TEST CONFIGURATION



Notes: (1) Data from HRM routed to an actual KUSP and to Room 1263.

(2) Output of flight-type KUSP goes to a roof antenna for radiation to MILA and re-transmission to the JSC POCC.

(3) GPC is scheduled for installation in CITE in 1982. KUSP is not currently funded.

Figure E-5. CITE TEST CONFIGURATION

transported from the O&C Building to the OPF for installation in the Orbiter cargo bay. The final Spacelab test activity (conducted in the OPF) verifies the actual Spacelab/Orbiter connections. Since the flight configuration is utilized, only those uplink/downlink channels available during flight are available for test event command/monitoring. Uplink/downlink control is exercised from the firing room located in the OPF.

The 50 Mb/s data stream (channel 3, mode 1) from the HRM is Viterbi-encoded within the KUSP to 100 Mb/s and used to modulate the 15 GHz carrier. An RF coupler (Figure E-6) inserted in the line to the Orbiter Ku Band antenna taps off some of the RF energy. The Orbiter antenna is covered with an attenuating "hat" during testing to reduce the RF field strength within the OPF. The energy from the coupler is split, part of it going to an antenna on the roof of the OPF for transmission to JSC and the rest going to GSE racks in the OPF. The OPF GSE performs demodulation, Viterbi decoding and conversion of the 50 Mb/s data stream to an optical signal. The fiber optics cable is routed to the O&C Building where the signal is processed the same way as in the CITE test.

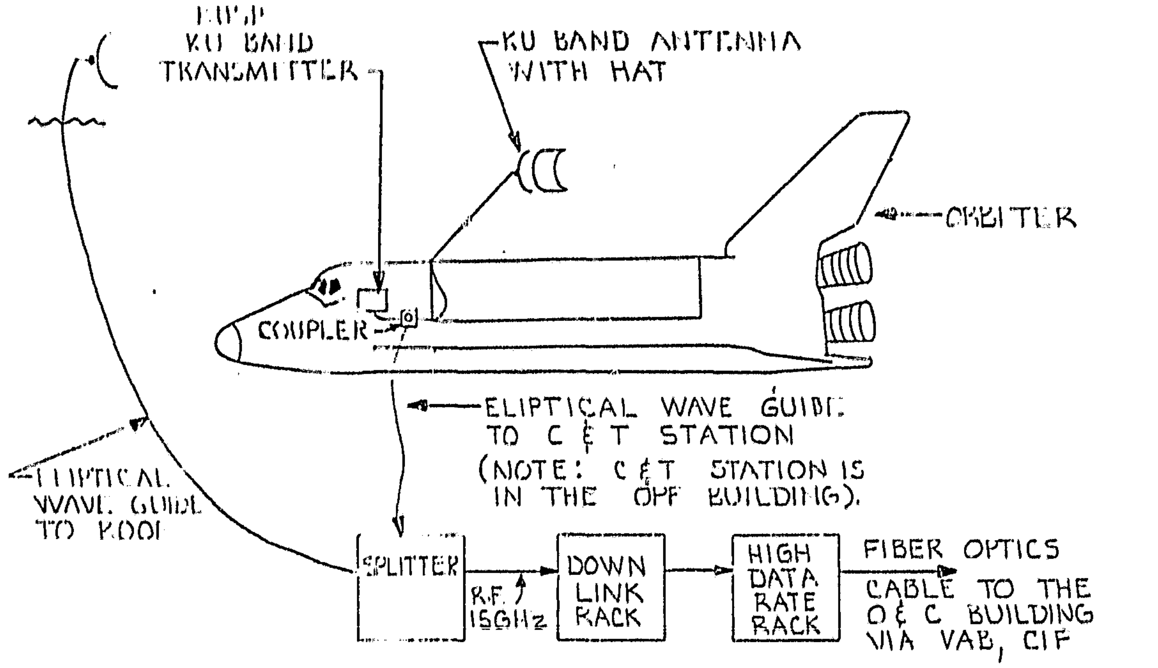
E.5 PAD OPERATIONS

There are no plans to operate the HRM at the pad. However, from a technical standpoint, there is a signal path via an RF link from the pad to the OPF and the fiber optics cable from the OPF to the O&C Building. (Refer to Figure E-1).

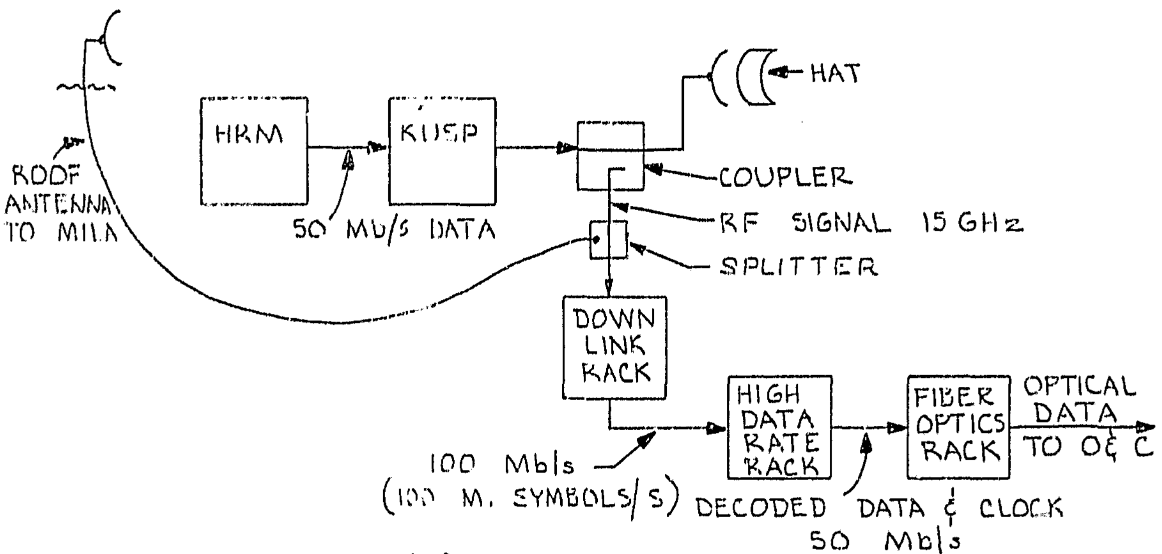
E.6 IMPACT OF CONVERTING SPACELAB TO PACKET TELEMETRY FORMAT

There appears to be no impact to KSC systems, services or operations if Spacelab is converted to a packetized telemetry format, provided the Ground Hybrid or Minimum Impact Hybrid approach is used. The rationale for this conclusion is as follows.

Both the Ground Hybrid and Minimum Impact Hybrid approaches rely upon the experiment itself to generate the packet format for data entering HRM high rate channels. The transparent HRM-HRDM downlink will then reproduce the same packet stream on the ground. Low rate data acquired by RAU's



(a.) PICTORIAL DIAGRAM



(b.) SCHEMATIC DIAGRAM

Figure E-6. OPF TEST CONFIGURATION

is downlinked in exactly the same ECIO format as is used now. The only change is at the Goddard Space Flight Center Spacelab Data Processing Facility (GSFC SLDPF). The SLDPF is modified to provide rapid delivery of high rate packets and is augmented to packetize ECIO data concurrently with the decommutation process.

Suppose it is assumed that the SLDPF has been modified as above and that a packet-generating experiment arrives at KSC for integration. The Principal Investigator (PI) must provide his own IGSE to analyze the high rate data from his experiment. KSC provides only the cabling to connect the two. Consequently, KSC systems and services are independent of the formats chosen by experimenters on the high rate channels, and therefore are not impacted by the presence of packets on these channels. As for the ECIO data, by locating the packetizer at th SLDPF rather than on board Spacelab, KSC and JSC POCC systems are spared any impact. The ECIO data stream downlinked by the HRM/HRDM will remain the same at KSC and JSC as it is now. Consequently, no hardware or software changes are needed at either center.